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A modernization plan for the Technical Data Department of the Naval Ships Weapon Systems Engineering Station

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A MODERIZATION PLAN FOR THE TECHNICAL DATA DEPARTMENT OF THE NAVAL SHIPS WEAPON SYSTEMS ENGINEERING STATION

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THESIS

A MODERNIZATION PLAN FOR THE TECHNICAL DATA
DEPARTMENT OF THE NAVAL SHIPS WEAPON
SYSTEMS ENGINEERING STATION

by

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and
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September 1976

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I. INTRODUCTION

The overall objective of this thesis is to establish a foundation which can be utilized by the Naval Ship Weapon System Engineering Station (NSWSES) in the development of a modernization plan for the stations data management system. The intent is to provide an understanding of the scope of the considerations which impact the development of the data management system. A framework is presented which will assist NSWSES in insuring that these considerations are taken into account during the specification of system requirements.

A. METHODOLOGY

The methodology presented here was devised by the authors to provide for an intraorganizational structure to coordinate a modernization that includes the acquisition of facilities involving high technology. The output of this method is not to describe what should be done at a particular point in time but what key organizational structures should be formed to coordinate the process and what the critical issues lie under the aegis of specific components of that structure. A diagram of the procedure is shown in Fig 1.

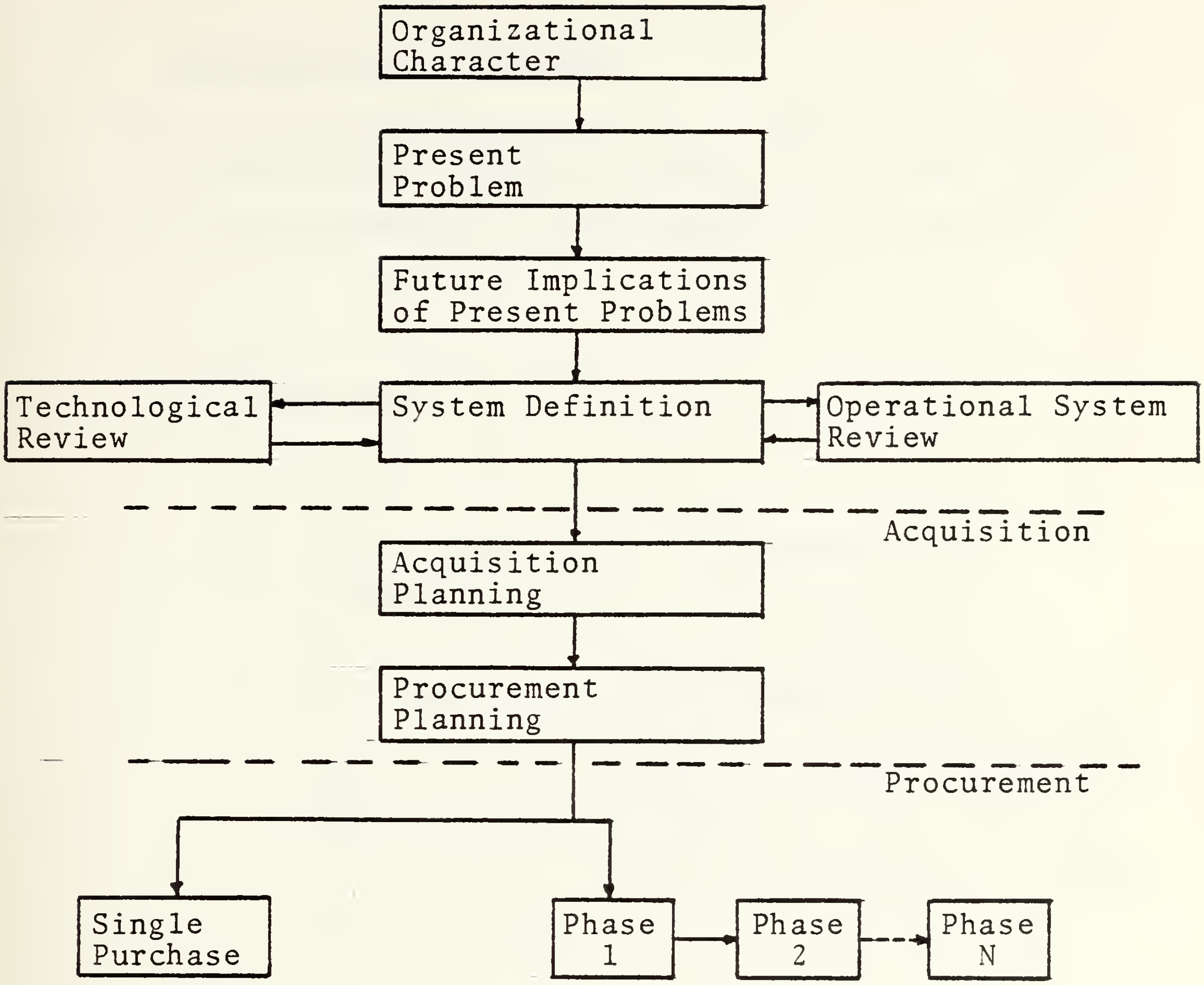

Figure 1 - METHODOLOGY BLOCK DIAGRAM

1. <u>Organizational Character</u>

The first consideration is to clearly define the character of the organization that will undergo the change. The key questions to be answered in this section are as follows:

a. Organizational History

1. How did they evolve?

2. What external factors influenced this evolution?

3. Was there a normal growth pattern or did they experience elements of revolutionary growth? An example might be an uncharacteristic increase in materials, facilities, or labor to support an added responsibility.

b. Organizational Structure

1. What is the structure? functional? vertical? etc?

2. What are the formal/informal lines of communication?

3. What are the specific responsibilities of each component?

c. Organizational Process

1. What are the inputs to each component?

2. How does each component utilize its resources to process these inputs?

3. What are the outputs?

4. Who are the users of these outputs?

d. Organizational Procedures

1. What are the specific procedures that each component uses in fulfilling its function?

2. How do these procedures mesh with those of other components?

2. <u>Present Problems</u>

With a clear understanding of what use the organization serves and how it fulfills its responsibilities, an assessment may be made as to the real nature of the problems that presently exist. These problems may be related to structure, process, procedures or a combination of these. Since we are concerned with a modernization process, it is likely that key elements of the problems lie in factors which are external in nature. These may be in the form of additional responsibilities, unforeseen growth (evolutionary or revolutionary), or increased responsibility to users that are outside the organizational structure.

It is not sufficient to simply identify the problems that now exist. In addition, the elements of the causes of these problems must be identified. This is not to suggest that a simple single cause/ single problem relationship exists but a "group" of causes that manifest themselves in a "group" of problems must be identified. This forms the basis of projection of how the nature of the identified problems might change in the future.

3. Future Implications of Present Problems

Depending upon the degree of change that the organization is expected to undergo and possible budgetary constraints, the process may take from a few months to a number of years. To assess the degree of modernization needed, the effect of the "causes" identified in the preceeding section must be projected to a time in the future when the modernization is expected to be complete. Since the term "cause" is somewhat static, the authors will now shift terminology to give a more temporal connotation and use the term "variable". A variable is a cause that changes over time.

The techniques for projection of these variables may vary from informal discussions with key individuals, who are both internal and external to the organization, to sophisticated statistical procedures depending upon the amount and nature of the data available. If characteristics of these variables are not quantifiable, individual expertise must be used. If the characteristics can be converted to numerical parameters, statistical forecasting techniques involving evolutionary growth and confidence intervals may be applied.

Not all the variables are expected to increase in their impact. It may be that by the time the modernization process is complete, some variables may decrease or even be of no significance at all. Also, unforeseen variables may appear and have significant impact during the process. This is to illustrate that this methodology is a dynamic process. There is no separation between planning and implementation since this might lead to a solution to problems that no longer exist and to problems that the solution does not address. Only through continuous review of the nature of the variables can these traps be avoided.

4. <u>System Definition, Review of Technology and Operational Systems</u>

The system definition is the first step toward identifying the specific hardware characteristics of the solution. The specific functional needs of the organization should be apparent after the analysis described in the previous section has identified the impact of the variables in the future. Using these expected variable characteristics, the initial formulation of a general equipment configuration may proceed. The system definition is the buffer between the general functional characteristics and the specific technical parameters of the actual hardware. It is an initial identification of the possible technical alternatives and defines the areas of technological review.

The initial review of technology is not an assessment of specific hardwares of specific manufacturers. It is a general investigation of the industries, which appear to be developing products that will satisfy the need, to ascertain what the characteristics of their products might be when the procurement phase begins. The technological review will then impact the system definition by indicating the risk associated with each alternative. Future iterations through this review cycle will serve to refine the definition until specific hardware characteristics are extracted.

The review of presently operating systems which are similar to the system conceived in the definition will facilitate learning by what others have done. There is certainly no disgrace in patterning the characteristics of the solution after a system which is operating effectively at the present time. This review can provide critical information on possible pitfalls as well as a sound basis upon which to apply new technicalogical advances which might improve performance. It may also provide an insight to possible changes in organizational structure required by a more modern technical approach.

Again, the authors would like to emphasize that this process of establishing a system definition, based on the variables, and iterating it through technical and operational system reviews is dynamic. It must be a continuous process so that when the hardware characteristics are definitized in a legal contract they will 1) support a system that is consistent with the projected nature of the variables, 2) utilize a technology that will be neither obsolete nor unattainable and 3) reflect the considerations of other systems to avoid replication of errors and to embrace sound technical and organizational procedures.

5. Acquisition Planning

To avoid confusion, the authors will now draw a distinction between the terms "acquisition" and "procurement". For the purposes of this thesis, the process of acquisition involves planning, coordination, tradeoff analysis, cost estimating, procurement planning, procurement, and assessment of the procurement activity. Procurement is a subset of acquisition and involves contract definition, installation, checkout, and phased-in operation.

Acquisition planning is the allocation of internal personnel resources to most effectively plan and coordinate the modernization. For complex systems involving large capital outlays, phased-in operation, and consideration of a number of alternatives with varying degrees of risk, a steering committee structure might be advantageous. For less complex purchases, coordination might be limited to a few upper/middle level management personnel.

The steering committee structure would involve a limited number of key decision makers but with the support of other personnel serving on subcommittees that are involved with various key aspects of the acquisition. Each subcommittee would iterate through the system definition cycle as previously described while the main committee members would assimilate their data, make tradeoff decisions and finalize the procurement plan.

The actual configuration of this acquisition planning section will depend upon the nature of the organization, the complexity of the modernization, and the availability of intraorganizational expertise.

The major output of acquisition planning is the procurement plan. If the system is a single purchase, this plan would give the specific hardware characteristics that are required in the contract definition. If the purchase involves seperate phases, the plan must contain the following:

a. Specific hardware characteristics for Phase 1.

b. An intergration plan showing the relationship of all phases to the end objective.

c. A timing plan to coordinate milestones within each phase as they relate to milestones in other phases.

To amplify this third requirement, an acquisition must assess how well a particular phase supports the overall objectives. The beginning of the next phase need not wait until after this assessment. Contract definition work by various subcommittees may begin during phase-in or even earlier if the risks are not great. The restriction would be that the contract should not be let until some assessment of the previous phase has been made. If the assessment gives indications that the effort was insufficient, additional work may be needed in the next phase. If the assessment shows that the system was operating better than expected, subsequent phases might be reduced or even elimated.

This methodology will now be used to address the NSWSES modernization.

B. HISTORICAL BACKGROUND

During the latter part of World War II and in subsequent years the Navy has continued a concentrated effort toward the development and installation of highly complex weapon systems aboard Navy surface ships. The rapid advance of technology has made possible the deployment of very sophisticated and highly capable weapon systems. Taking advantage of this technology has carried with it an ever increasing requirement for engineering, logistic and technical support. The need for a field activity which could provide a concentrated source of these support requirements for Surface Missile Systems (SMS) led to the establishment of the Naval Ship Weapon Systems Engineering Station (NSWSES) at Port Hueneme in 1963.

The station's first and primary task was to upgrade the reliability and performance of the Terrier, Tartar, and Talos missile systems which were then deployed in the fleet. As a foundation for providing total system support, a configuration baseline was established from data collected through direct contact with the fleet and from system contractors. This technical data base, established at the very beginning and upgraded and expanded through the years, has continued to be the most important ingredient to the in-service engineering and in-service logistic support through which NSWSES has gained its excellent reputation in the fleet. The station's Technical Data Department provides the centralized location for the storage, updating and retrieval of this technical data.

The responsibilities of NSWSES have grown over the years, along with its reputation, and station personnel are now involved in the support of many systems in addition to surface missile systems. These systems include some Gun Fire Control systems, Surface Weapons Switchboards, Search Radars, the AEGIS program, the Anti-Ship Missile Defense System, the Point Defense System, the Standard Missile, Nato Sea Sparrow and the Harpoon Missile as well as the continued support of the original Terrier, Tartar and Talos Missile Systems.

These greatly expanded responsibilities along with the ever increasing technical complexity has made the task of technical data management and configuration management even more essential today than it was in 1963 when NSWSES was established. The Navy has recognized the importance of technical data by including data as a segment of the Integrated Logistics Support program developed in the 1960's. The Integrated Logistics Support program makes the proper maintenance of a technical data base an integral part of the weapons system life cycle.

Because of the broader areas of responsibility being assumed by NSWSES, increased weapon systems complexity, and necessary emphasis on proper technical support, the Technical Data Department remains as an important factor in the ability of NSWSES to continue its service to the fleet. To meet the future requirements for accurate and timely technical data support the department must seek new and improved techniques to update, store and retrieve technical data.

The data management system currently in use in the Technical Data Department is based on the data management and storage technology which existed in the early to middle sixties when the station was founded. Changes to the system which have occured have been largely evolutionary in nature and have been in response to the increasing volume of the data base and increasing number and needs of the users of the data base. As new specific requirements have been identified, new files have been created, new reports have been generated and specific output products have been developed. While this method of response to system demands has been successful in the past in meeting users needs, the system resources are being increasingly strained to meet the time and accuracy requirements of today's data operations and configuration management. NSWSES personnel have indictated that the data files which have been developed are not well integrated, leading to redundant storage of data and inefficient methods for manipulating data often involving several manual steps which could be automatically performed with modern data management techniques.

II. CONFIGURATION MANAGEMENT - THE PRESENT SYSTEM

A. SYSTEMS SUPPORTED

The type of systems supported by NSWSES was briefly discussed in Chapter I. The amount of support for these systems is a function of the degree of NSWSES involvement. This may be as little as a specific task to correct a given problem or as much as total engineering support including logistics and data management. In the past this has been an evolutionary growth beginning with a technical involvement and proceeding to logistics and data management as the station gained in engineering expertise.

As the concept of the totally integrated weapon system grows, more emphasis is being placed on equipments that interface with the major missile systems, such as, search radars and guns. Fig 2 shows the present systems which are completely supported by the Technical Data Department.

System	Subsystem	Designator	Number (1)
Terrier GMS			34 (3)
	GM Launching System	MK10 Mod0-9	46
	GM Fire Control System	MK71 Mod0-1 MK73 Mod0-1 MK76 Mod0-9	98
	Weapons Direction System	MK1 Mod0 MK3 Mod0-3 MK5 Mod0-2 MK7 Mod0-3 MK11 Mod0-4	33
Tartar GMS			52 (2,3)
	GM Launching System	MK16 Mod4 (Modified) MK11 Mod0-2 MK13 Mod0-4 MK22 Mod0 MK26 Mod0-2 MK32 Mod0-1	52 (2)
	GM Fire Control System	MK74 Mod0-8	54 (2)
	Weapons Direction System	MK4 Mod0-5 MK13 Mod0-1 MK14 Mod0	42 (2)
Talos GMS			5 (3)
	GM Launching System	MK7 Mod0 MK12 Mod0-1	7
	GM Fire Control System	MK77 Mod0-4	5
	Weapons Direction System	MK2 Mod0-1 MK6 Mod0-3	4

Figure 2 - SYSTEMS COMPLETELY SUPPORTED

System	Subsystem	Designator	Number (1)
Basic Point Defense			50 (3)
	GM Launching System	MK25 Mod0-1	50
	GM Fire Control System	MK115 Mod0	50
5" Gun			2 (3)
	Gun Fire Control System	MK86 Mod3-5	2
AN/SPS-58 Search Radars			11 (3)
Ancillary Equipment		208 Types	Numerous

Notes:

1. Number of ships with this system
2. Includes Tartar used only for surface capability
3. These numbers are those on U.S. ships although some services are provided to allied governments.

Figure 2 - SYSTEMS COMPLETELY SUPPORTED (Continued)

B. TECHNICAL DATA DEPARTMENT

The two divisions comprising the Technical Data Department (Code 5100) are the primary source of configuration and data management for NSWSES systems (see Fig 3). The department is tasked with coordination and control of data requirements for NSWSES supported equipments throughout their life cycle. In fulfilling this requirement, the department becomes involved with data acquisition at a detailed level including: identification of need, procurement coordination, validation, standardization, quality assurance, review and revision of existing policies and standards, and cost analysis. Furthermore, the department must develope and maintain an Integrated Configuration Management Data System (ICMDS) to provide baseline identification, configuration status, and associated engineering planning for designated ship, sites, systems, equipments and configuration items.

1. Data Management Division

The Data Management Division (Code 5120) specifies and standardizes the content, form, and production of technical data. It monitors, reviews, and provides services for preparation, acquisition, and release of technical data. Furthermore, the division authenticates and releases complete design disclosure information subsequent to approval of the documentation by the appropriate engineering department. The division is divided into three branches: Data Requirements Branch (Code 5121), Data Standardization Branch (Code 5122), and Design Disclosure and Review Branch (Code 5123). Each of these branches acts as an initial input and a prospective user of ICMDS.

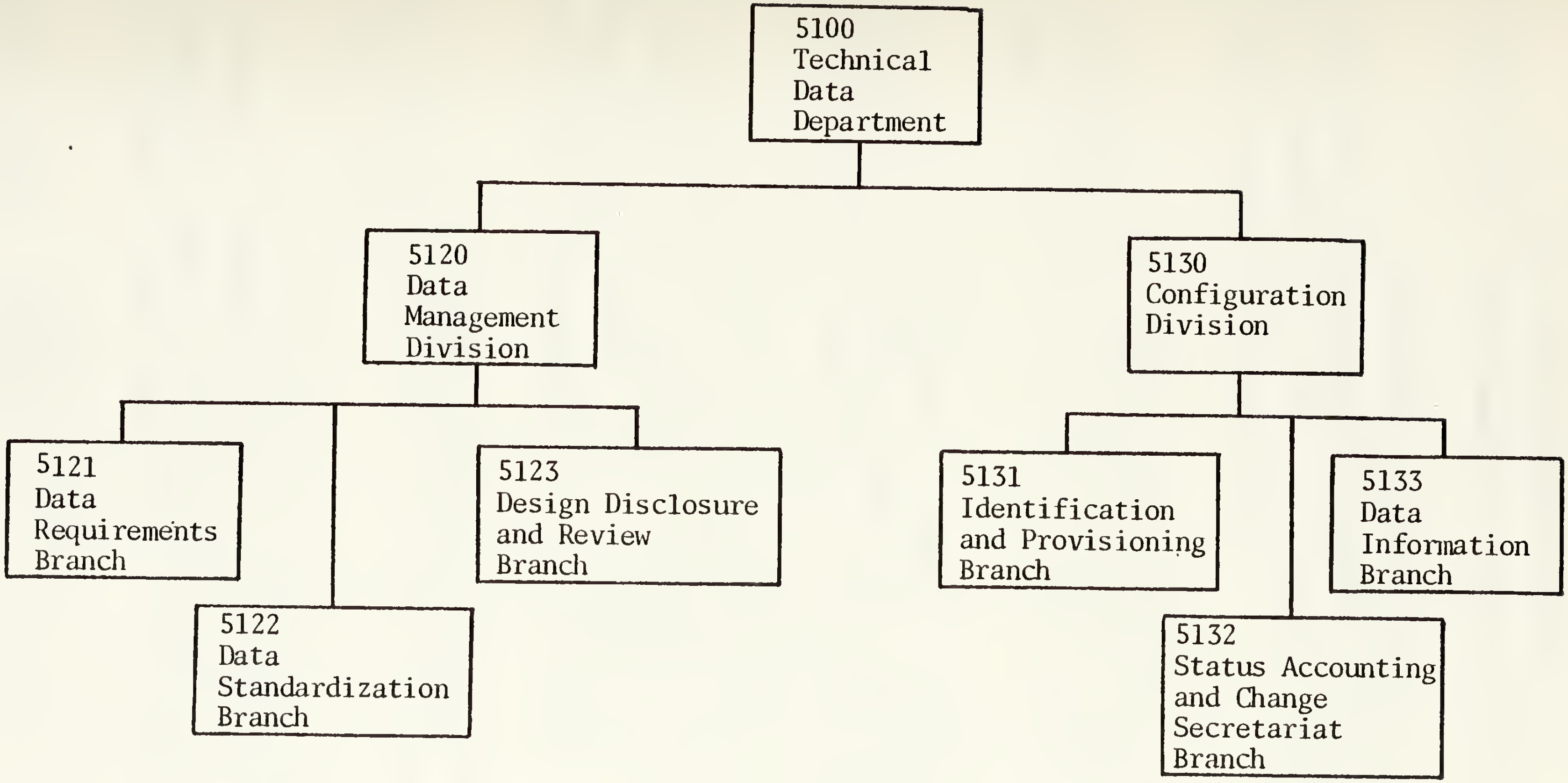

Figure 3 - TECHNICAL DATA DEPARTMENT

a. Data Requirements Branch

The specific requirements of this branch are as follows:

1. Evaluate data of existing systems and their interfaces cn proposed procurement actions during all phases of the system life cycle to determine the range and depth of technical data to be procured.

2. Select data items for procurement from authorized data lists and provide for acquisition of minimum data essential to satisfy requirements of all intended users.

3. Develope general technical data cost estimating standards, based on cost analysis of prior acquisitions and knowledge of production processes.

4. Review data procurements in conjuction with engineering codes, design agents, and procuring agents to determine if revisions, waivers, and deviations are necessary as a result of a request for change in shop operations and scope/contract requirements.

5. Prepare Contract Data Requirement List (CDRL) DD 1423 for approval of the Data Requirements Review Board (DRRB) Chairman.

6. Ensure that sufficient data are ordered to provide for adequate design disclosure, including quality assurance, special processes, drawing specifications, etc., as dictated by the complexity of the procurement.

7. Provide representation for the department as Data Element Managers for integrated logistics support

and/or operational logistics support teams.

8. Review and evaluate requests for technical documentation that is not available in the data repository.

9. Review technical data acquired by NSWSES and inspect for conformance with standards, specifications, and quality criteria specified by the procurement document.

b. Data Standardization Branch

The specific responsibilities of this branch are as follows:

1. Prepare, revise, and maintain specifications, standards, and other technical data required to fulfill intended use and that will conform with design objectives and qualitative requirements of DOD, NAVSEA, NAVSHIPS, and NSWSES directives.

2. Preform in-process reviews to assure adequacy, standardized form, and content of technical data prepared by or for NSWSES.

3. Maintain status accounting of Ships Weapon System Specifications and Ordnance Data.

4. Assist acquisition in the identification of technical data not available from normal sources of supply.

5. Analyze and evaluate specification change/documentation and establish the change procedure.

6. Assign and control NAVSEA drawing, sketch, WS and OD numbers for NSWSES.

c. Design Disclosure and Review Branch

The specific responsibilities of this branch are as follows:

1. Provide guidance and support to data preparing agencies concerning interpretation of DOD, Navy, and NSWSES instructions and specifications, controlling preparation of data and adequate structure of the disclosure package.

2. Provide and manage in-process review teams for systematic review of technical data under preparation, ensuring progressive development of disclosure information and producibility of end items.

3. Develope engineering guidelines for review of contractor documentation programs to ensure compliance with DOD requirements pertaining to quality of data.

4. Identify and/or verify deficient areas in existing technical data packages; recommend resolution of problems.

5. Review and evaluate Engineering Change Proposals (ECPs) for data content and cost for presentation and approval to the CCB.

6. Analyze and evaluate technical data change documentation to identify and/or verify deficient areas.

7. Review requests for approval of non-standard parts, in conjuction with cognizant engineering codes, to determine compliance with applicable military standards.

2. Configuration Management Division

The Configuration Division (Code 5130) acts as the NSWSES point of contact for configuration matters, performs configuration planning, identification, status accounting, change control coordination, and configuration audits. The division is divided into three branches: Identification and Provisioning Branch (Code 5131), Status Accounting and Change Secretariat Branch (Code 5132), Data Information Branch (Code 5133). Each of these branches is responsible for maintaining a file which directly supports ICMDS.

a. Identification and Provisioning Branch

The specific responsibilities of this branch are as follows:

1. Select, correlate, and review accumulated approved documentation to ensure disclosure of configuration identification and its suitability for use in preparation of provisioning data.

2. Prepare and maintain configuration listings of designated systems, system segments, equipments, assemblies, and other configuration items.

3. Monitor and evaluate contractor efforts in the preparation of configuration identification and provisioning data.

4. Administer an information handling system for the storage, correlation, maintenance, retrieval, reporting of configuration identification, and preparation of provisioning technical documentation.

5. Recommend provisionable items and prepare provisioning technical documentation, support material, and other similar provisioning documentation.

6. Review and evaluate Engineering Change Proposals (ECP) for provisioning requirements.

7. Participate in provisioning conferences and in maintenance and review of Allowance Parts Lists (APL).

In order to support the above functions, the branch maintains the Configuration Item Identification File (CIIF). The CIIF provides storage and retrieval capability for technical and logistics data specified on an engineering drawing. A more detailed discription of the CIIF, its inputs and outputs, and its users is contained in Section IIC.

b. Status Accounting and Change Secretariat Branch

The specific responsibilities of this branch are as follows:

1. Select, correlate, and accumulate approved technical discription documentation required to achieve complete and current accounting of designated and installed equipments; record the status of approved and proposed changes.

2. Administer the information for storage, correlation, maintenance, retrieval and reporting of configuration status records.

3. Maintain liasion with appropriate activities for the exchange of configuration status information and validation of configuration records.

4. Develope configuration management data in support of fleet and shore activities and prepare and distribute configuration management reports and associated engineering and planning data.

5. Indoctrinate, monitor, and evaluate contractor efforts in the preformance of configuration status accounting.

6. Act as principle input source and ensure the validity of designated data from other sources in the Ships Equipment Configuration Accounting System (SECAS).

7. Act as point of contact between NSWSES and external Configuration Control Board (CCB) secretariats; provide representation to NSWSES CCB.

8. Indoctrinate NSWSES and contractor personnel in configuration control requirements and aid them in the preparation of Engineering Change Proposals (ECP).

9. Control and assign NSWSES ECP numbers; assign/obtain procuring activity numbers where required; distribute ECP and monitor the ECP review process on station.

10. Check incoming and outgoing ECP review packages for completeness, consistiency and compliance to existing directives; initiate corrective action where required.

To support these functions, the branch maintains two Configuration Status Accounting (CSA) files. The Site File contains discriptive information of all NSWSES cognizant equipment as well as site location data. Information includes sub-system usage, EIC, nomenclature, designation and serial number. The Class 1 Change File contains information on applicabile equipment changes including purpose, logistic data, where applicable, and authority. More detailed information on these two CSA files is contained in Section IIC.

c. Data Information Branch

The specific responsibilities of this branch are as follows:

1. Provide continuing technical direction for evaluating, improvement, and control of the information handling system, related facilities and equipments.

2. Coordinate with the ADP System Division and other cognizant organizations concerning automated retrieval, update, and refiling of information. Assure compatibility with other digital data repository programs.

3. Accept or reject data recieved from outside suppliers, applying appropriate standards for physical and image quality to ensure that data introduced into the repository are satisfactory for intended use.

4. Maintain the NSWSES repository of microfilm recieved through automatic distribution or through specific acquisition action.

Supply technical data in response to user requests, following established procedures and techniques for identifying, locating, accounting, retrieving and reproducing the data.

5. Provide complete reference library services

for NSWSES and other authorized organizations.

In order to support items 1-4, the branch maintains the Automated Aperture Card File (AACF). This contains computer cards with affixed microfilm of engineering drawings of NSWSES supported equipments. Additional information on the AACF is contained in Section IIC.

C. FILE CHARACTERISTICS

The interaction of the Configuration Division and other agencies is predicated on the division's capability to transmit timely information in the useful form to the prospective user. All information is concentrated in the four files previously mentioned. The following is a discription of the inputs, outputs, users, and maintenance procedures for each of these files.

1. Site and Class 1 Change Files

The Site and Class 1 Change files are stored on two reels of magnetic computer tape. The Site file covers approximately 575 sites and 1600 equipments. The Class 1 Change file contains approximately 4500 changes affecting equipment configuration. These changes may be in the form of Engineering Change Proposals (ECP) or Ordnance Alterations (ORDALT). An ORDALT is a change which has been reviewed as an ECP and authorized for accomplishment on Fleet equipments. Approximately 1200 ECP's and 167 final ORDALT texts are processed through these files yearly.

a. Inputs

The following are the primary sources of information used in maintaining/updating these files:

1. Contractor Hardware Configuration Lists (HCL) provide serial number, destination, date shipped from contractor, and ORDALTs installed in production equipments.

2. 180 Day Letter from ships scheduled for regular overhaul provide "scheduled for installation" information.

3. Site Inventories provide a validation of current file information as well as a baseline for new site/ships.

4. DD 250's that reflect receipt of ORDALTs/equipments are inputed to the files.

5. Configuration Inspections held by NSWSES engineering codes use a file extract as a reference. The marked up copy reflecting changes in configuration is returned and used to update the existing files.

6. Ships Armament Inventory List (SAIL) change reports received in NAVSEA, that pertain to NSWSES cognizant systems/equipments, are forwarded for validation and subsequent inputing to SECAS files at NWS Concord. As a result of this effort, NSWSES files are consistent with corresponding SECAS files.

7. All NSWSES message traffic is screened for impact on the subject files.

b. Outputs and Users

The following is a list of the more common output products and the users most interested in these products:

1. <u>Configuration Index</u> - This report is produced for shipboard application. It provides ship's personnel with current configuration and serves as a cross reference to identify and locate microfilm needed to accomplish equipment maintenance.

2. <u>Equipment Sequence Extract Report</u> - This report provides the applicability/status of NSWSES cognizant ORDALTs. It is arranged by system, then equipment, then applicable ORDALTs. The report is used by configuration management activities for current equipment change status.

3. <u>Site/Equipment Where-Used</u> - This report provides a quick reference of NSWSES cognizant equipments by serial number and location. It is used by data management support, publications support, and logistics support activities as well as engineering codes.

4. <u>SMS Site Index</u>- This report provides a listing of NSWSES cognizant equipments aboard each ship or shore activity. The report is used for file maintenance, configuration management, data management, logistics management, publications management, and both NSWSES and contractor engineering support activities.

5. <u>MOC Transaction Tape</u> - This report is a translation of NSWSES data on ORDALT status update information into the form used by the Master Ordnance Configuration (MOC) file which is part of SECAS. The tape is used by the Ordnance Maintenance Management Information

Center (OMMIC) at Concord, CA. to update the MOC file.

6. Inventory Management File Data Report - This report provides the applicability and installation status of NSWSES cognizant ORDALTs and summarizes the inventory management data. The users of this report are NSWSES inventory management codes and Ships Parts Control Center (SPCC) at Mechanicsburg, PA.

7. Monthly Data Audit Report - This report provides total display of all data in the Class 1 Change file. It is arranged in ORDALT sequence by system (Terrier, Tartar, etc.). The report is used for file maintenance, configuration management, and both NSWSES and contractor engineering support activities.

8. SMS Installation Status - This report provides applicability and installation status of all NSWSES cognizant ORDALTs. It is used by configuration management specialists and engineering support groups for ship ROH planning.

9. Configuration Management File Report- This report provides data relative to a specific improvement planned for a class of ships. The report identifies the improvement, lists applicable ships, and tabulates all cost items. The report is used by improvement planning groups for cost projection and procurement milestone monitoring.

10. Cross Reference Index- This report provides a cross reference of Class 1 Engineering Changes by 1) ORDALT number, 2) Navy Control Number, 3) SHIPALT number, 4) ECP by originator number. It is used as a reference document for configuration management, engineering support, data management, and publications management.

2. Configuration Item Identification File (CIIF)

The CIIF is stored on 17 reels of magnetic computer tape. The file covers all major SMS and some Gun Fire Control Systems (GFCS) equipment (less expendables and missiles). It also covers all SMS test equipment, 6 guided missile checkout equipments and 193 ancillary equipments. These system responsibilities result in approximately 3 million line items and is/was data on over 550 active ORDALTs. Approximately 10 major equipment provisionings, 5 minor equipment provisionings, 60 ORDALTs, and 5 APL reviews are processed through this file yearly.

a. Inputs

The original entry of a new system or equipment into the CIIF is accomplished either by conversion of a contractor magnetic tape or manual entry. Change data is entered into the CIIF when the change has been finalized and authorized/approved and revision control drawings are available.

b. Outputs and Users

The following is a list of the present output products and the users most interested in these products:

1. CIIF Where Used List - This report is an alpha-numeric listing of all items in a subject file giving the next higher drawing number for each item. The report is used for file maintenance, engineering support, shipyards, and repair facilities.

2. Configuration Index Listing - This report is divided into three sections. Section 1 lists all reference designators for assemblies and the sequence number of that item. Section 2 is the military designator index. Section 3 is a top-down breakdown to the lowest assembly level and includes schematics and wiring diagrams. The report is used as an equipment maintenance reference for shipboard personnel, engineering support personnel, NAVSEACENPAC, and NAVSEACENLANT.

3. Chain Index Listing - This report provides a top-down breakdown of a specific equipment or part from an equipment to the lowest assembly level. The report is used for file maintenance and engineering support.

4. ECP/Drawing Status File - This file relates each ECP to the drawings affected by that ECP. It is used by engineering support and data management activities.

5. Provisioning Parts List (PPL) and Consolidated Component Application List (CCAL) - The PPL is generated at the request of an Inventory Control Point (ICP) via a Provisioning Requirements Statement. The PPL is easily converted by the ICP into an Allowance Parts List (APL). The CCAL is an index for the PPL and is produced in reference designator sequence or in a top-down alpha numeric sequence. The PPL is supported by drawings, specifications, vendor data, etc.

3. Automated Apeture Card File (AACF)

The AACF consists of approximately 3 million master aperture cards and the corresponding computerized Master Inventory File (MIF). The inputs to both files are manufacturer drawings for supplied equipments and revised drawings from contractor or engineering codes. The aperture card file acts as a repository for engineering drawings supplied to ships, shipyards, repair facilities and engineering codes.

4. File Maintenance Procedures

Both the CSA files and the CIIF are maintained with the use of loading forms. Each file has a number of different types of forms depending upon the nature of the transaction. Once the transacton has been coded, the forms are key punched onto a magnetic tape and sent to the computer facility for processing.

At present, NSWSES has no dedicated computing facility. It utilizes the Naval Facilities Engineering Command (FACSO) facility which is located approximately two miles away. This results in a substantial time lag between runs during the update process because, 1) the computing facility is not primarily used for configuration management and therefore processing must be scheduled, 2) errors in loading forms or subsequent key punching are not caught until computer processing is completed and returned to the originator.

An example of this process is the CIIF parts listing function. This function is divided into two major areas: 1) generating a new bill of material for the CIIF and 2) updating bills of material already in the file. The procedure to parts list a new bill is as follows:

1. The bills are parts listed manually on loading forms.

2. The parts listed bills and loading forms are inspected for errors and filed until an update can be

scheduled. In some cases this is a month or more.

3. When an update is scheduled, a request for work is sent to the NSWSES Data Processing Department (Code 300) with the bill of materials and loading forms.

4. Code 300 forwards the work request and bills of material to the FACSO facility for keypunch, verification, master tape update and output listings.

5. The bills of material and listings are delivered to code 5131 where all indicated errors are corrected by repeating steps 1 through 4 above.

NSWSES personnel indicate that the average time required to perform a parts listing for an average equipment is five weeks. During this time, the data is not available to any user.

Maintenance of AACF requires more physical processing. When an engineering drawing is received, it is initially checked for resolution, density, proper format, and other MIL-standard specifications. The drawing is then filmed with a KODAK MRG 35MM or 3M 2000E camera to obtain a microfilm. The microfilm is used to key punch a slave deck. The microfilm is attached to an aperture card and these cards are run through an IBM reproducer with the slave deck to transfer the information from the slave deck to aperture cards. The slave deck is forwarded to the data processing center to update the master inventory file. After the aperture cards are interpreted to convert the keypunched information to print, they are placed into the AACF by using IBM collators. The collator automatically files the cards into the proper sequence and eliminates the need for human filing, thus reducing filing errors. The original drawings are sent to a local repository.

D. THE NEED FOR CONFIGURATION MANAGEMENT - AN EXAMPLE

The Mk 10 Guided Missile Launching System provides the launcher capability for the Terrier Guided Missile System. It is also used as a launching system for ASROC and HARPOON. The system has a history of reliable performance, ease of maintenance, and flexibility in responding to varying requirements. There are presently nine Mods to the launching system. Different Mods are used on missile capable aircraft carriers, double-ended and single-ended CGs, and DDGs.

From 1957 to 1975 the system had 60 Ordnance Alterations (ORDALTs). These ORDALTs were not applicable to all Mods but did affect an average of 40 ships per alteration. At present, 20 of these ORDALTs are outstanding in that they have not been completed on all ships to which they are applicable. The oldest of these outstanding ORDALTs was authorized in May of 1969. This means that over the last seven years, numerous configuration differences have existed in the launcher system in the Fleet. Even if each ORDALT was installed on all applicable ships simultaneously, thousands of possible combinations would exist.

There are many reasons why an alteration requires years to be completed throughout the Fleet. Many can only be performed during a restricted availibility or overhaul period. In many cases, funding restrictions require that an alteration be delayed until a second overhaul period which would occur approximately three years later.

Fig 4 shows the data for ORDALT 6865. This alteration was authorized for installation on February 1,1969. As can be seen from the graph, the first ship to have the alteration completed was DDG-41 in April 1970, and the last is CGN-9 which is presently in overhaul. This shows that over a period of five years a configuration difference existed in 34 ships of a varying degree.

The AACF impact of this ORDALT is 6 engineering drawings in addition to those of other alterations and the basic system. For the outstanding ORDALTs on the Mk 10 system, this number varies between 1 and 25. The impact on the CIIF is a listing of each drawing, the parts differences, and the relationship to the next higher assembly. The Class 1 Change file details all pertinant logistics and applicability data.

The Mk 10 Launching System was used for this example because of its stable nature. As a system, it has undergone comparatively few changes and has been in the Fleet for a number of years. For complex electronic systems, such as the AN/SPG-55 fire control radar, the changes are more numerous and have a greater impact on the major files.

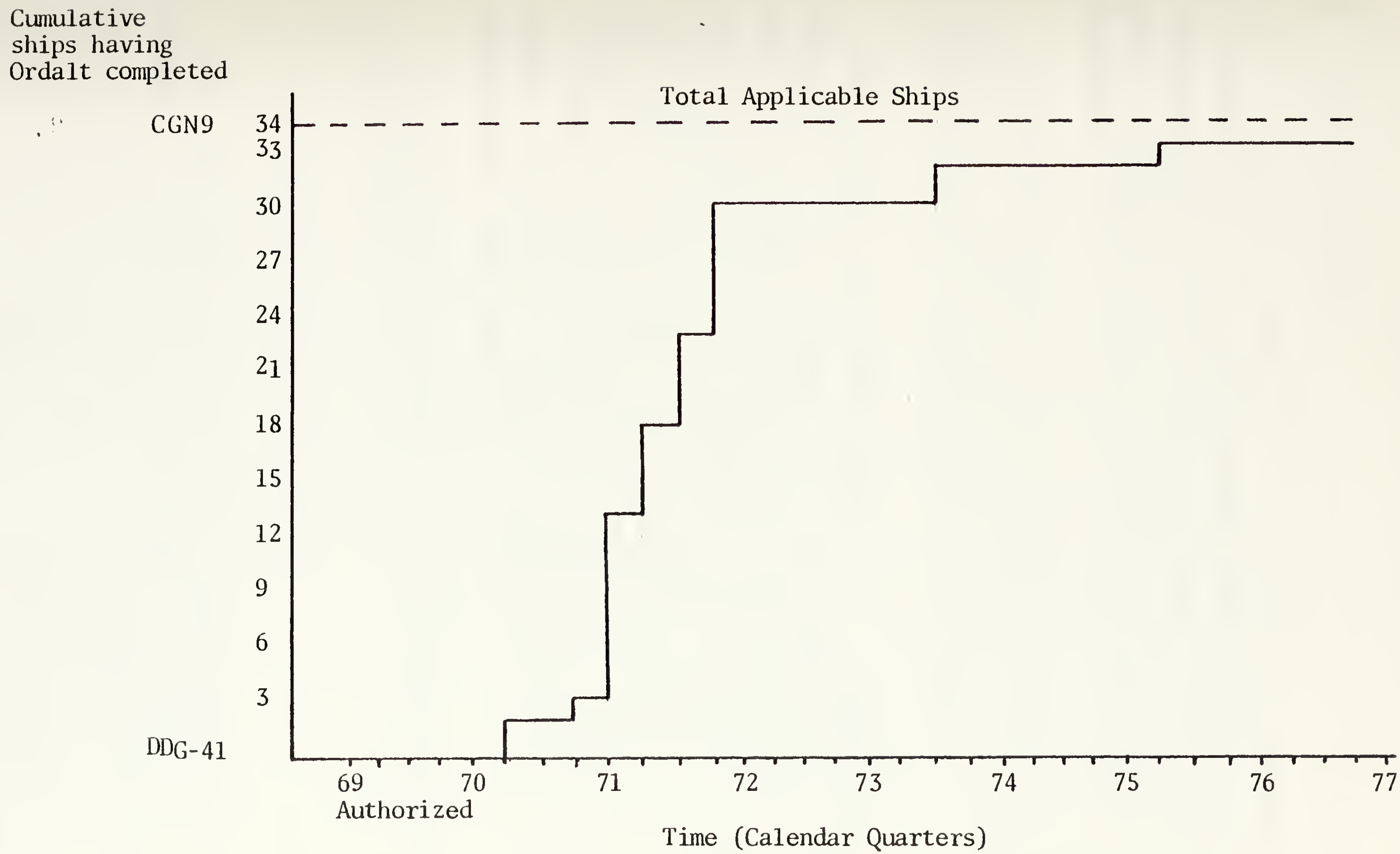

Figure 4 - ORDALT 6865 COMPLETION GRAPH

E. PRESENT PROBLEMS

In 1963 when the concept of configuration management was recognized as a viable management tool, NSWSES was primarily concerned with surface missile systems. At that time the SMS fleet consisted of 5 aircraft carriers, 10 cruisers, 22 frigates, and 25 destroyers or a total of 62 ships.

At present NSWSES has expanded in responsibility and is engaged in a variety of systems as shown in Section IIA. The SMS fleet has also expanded to 133 ships.

The impact of this growth in responsibility is manifested in a growth of all configuration files. The greatest increase has been in the size of the CIIF, the AACF and its supporting MIF. Presently, the data shows that files are growing at a rate of approximately 250,000 line items per year. As these files become larger, they become increasingly more difficult to manipulate. Present software is based on file structure technology that is nearly a decade old and as such, lacks flexibility and is increasingly time consuming to process.

The symptomatic problems caused by these characteristics are as follows:

1. Increased file update time.

As was noted in Section IIC, the procedure for updating requires considerable man-hours due to the need for loading form conversion to computer cards, scheduling of processing time, physical transportation of the cards to the computer facility and inefficient error correction methods due to the off-line nature of the process. This presently results in approximately five weeks wherein the data of that file is not useable.

2. Increased response time to users.

Because of the lengthy update cycle, user inquiries may be impossible to service until the data is processed. If the need is urgent, the user may be required to use the previous file information which is possibly in error. Users requiring tailored reports must be willing to wait until programming is made available for that specific format.

In Section IID, the authors presented an example of configuration differences and their impact on the Mk 10 Guided Missile Launching System. The data required for that example was extracted from the Class 1 Change File. Because that file has more than 240,000 records, the information was extracted by computer. This was a tailored request and would have required programming support and computer scheduling resulting in a rather long lead time before the data was available. To circumvent this, the authors requested a copy of the tape for that file and programmed and processed the file at the computer facility at the Naval Postgraduate School. The program was not difficult to write and use of the computer facility required no special scheduling. This resulted in a rapid extract of the data in the format required.

3. Increased potential for error.

The files require a large amount of human operation. Even the most experienced operator establishes a finite error rate for a given volume of activity. Unfortunately, as the volume of transactions increases, so does the absolute amount of errors even though the error rate might remain low. The result is that the update cycle becomes longer due to the greater number of errors.

4. AACF

Use of microfilm prints on aperture cards is of course more efficient and less time consumming than handling full size engineering drawings. But, because of the growth of this file, even this mode is requiring increased time. Departments that require the use of these cards must send messengers to pick up and account for the cards to provide file integrity. The retrieval system is slow as it requires each card to be pulled seperately with the use of slave decks and collators.

If a drawing is to be revised, it is obtained from the AACF, converted to hard copy, changed by the cognizant engineering department, redrawn by the draftsman, and reprocessed to the aperture card format. The average revision takes approximately 24 man-hours.

5. Lack of file integration.

Although all files are related by various common data elements, there exist no means by which one file may interrogate or transfer data to another without the use of loading forms. For example, if an Engineering Change Proposal (ECP) has final authorization, it impacts both the Class 1 Change File and the CIIF. At present, elements of this change must be processed seperately and by hand. The file relationships are shown in Fig 5.

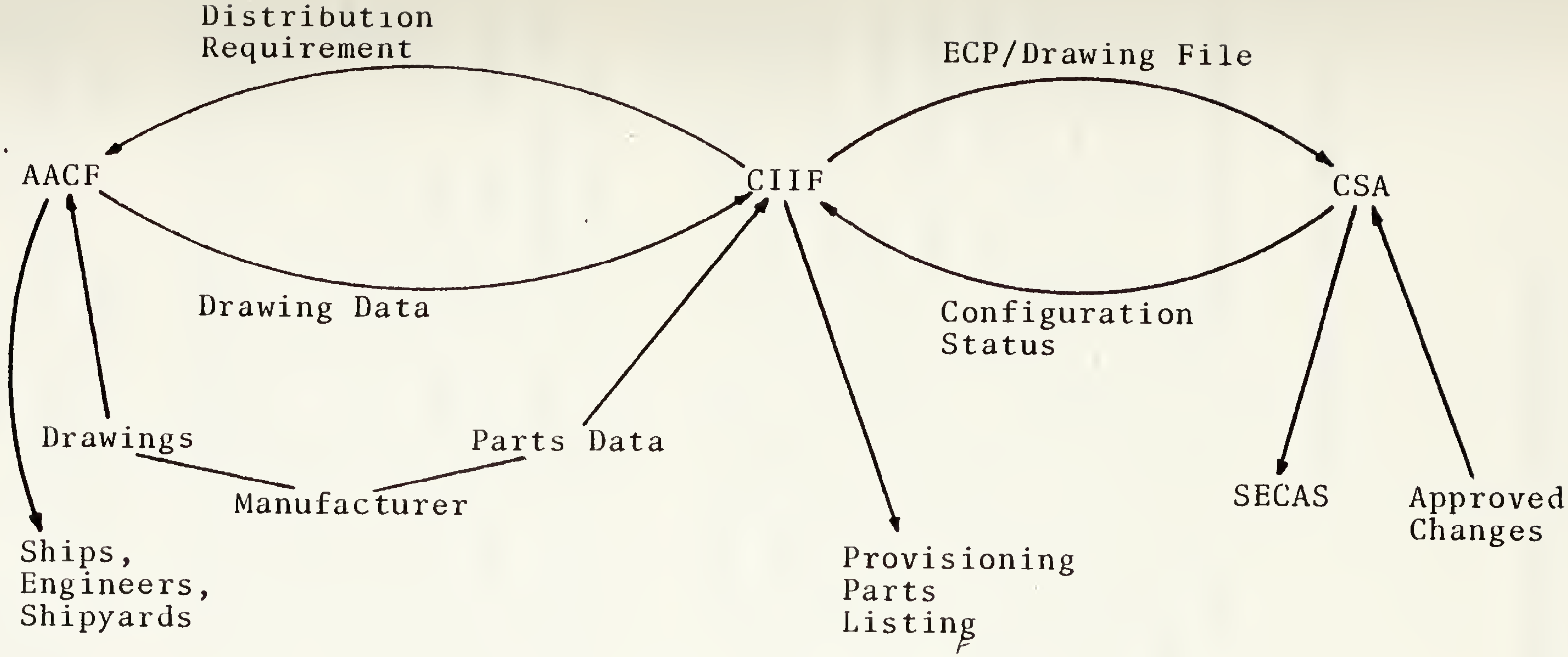

Figure 5 - FILE RELATIONSHIPS

III. CONFIGURATION MANAGEMENT - THE FUTURE DEMANDS

A. BASIS OF PROJECTIONS

General problems with the current system of data management in use at NSWSES were discussed in Chapter II. These problems were identified as excessive file update time, slow response to users needs, increasing potential for error with data volume, difficulty in manipulating the aperture card file and the lack of file integration. The magnitude of these problems in the future will vary directly with the volume of data which must be collected and stored and with the number and needs of the users of the data. In this chapter changes are identified which will effect the volume and useage of the data management system at NSWSES in the future.

Determination of what the future demands will be on the data management system is based as much as possible on changes which can be predicted with relative certainty, such as the approved Navy shipbuilding program, and on needs known to exist today. The development of a long range plan must also consider other events which may occur such as the expansion of the department's responsibility for configuration management to include systems which are now not under the department's control.

If a computer system is to be installed it is anticipated that it could be in operation in the 1980-81 time frame. It must be recognized however that any new system installed must be capable of meeting the needs of the department several years beyond the installation time. Therefore, some projections cover the 1980-85 time frame and the general trend of growth is anticipated to continue for the predictable future.

B. NAVY SHIPBUILDING PROGRAM

A major factor which will effect the data management needs of the Technical Data Department in the future is the Navy's shipbuilding program. The surface missile ships which are included in the program are of particular importance since the configuration of these ships includes many systems and equipments for which the configuration and data management divisions are responsible. Fig 6 sets forth the Navy's shipbuilding program for surface missile ships through 1981 as approved by Congress. These numbers reflect a major effort which is planned for expansion of the fleet.

	FY-76	FY-77	FY-78	FY-79	FY-80	FY-81	Total FY76-81
Carriers				1		1	2
Cruisers			1			1	2
Vistol Carrier					1		1
Destroyers		1		2	3	2	8
Frigates	6	8	8	8	8	8	46
Totals	6	9	9	11	12	12	59

Figure 6 - APPROVED NAVY SHIPBUILDING PROGRAM

C. SYSTEM DEPLOYMENT

In addition to the increasing size of the fleet it is important to consider the systems which are being installed on these ships and the systems which are being installed on ships which are already in commission. The projections for system deployment are based on recommendations made by the Anti-Ship Missile Defense Project Office (PM-20). Fig 7 lists several major systems for which NSWSES has the responsibility for some aspect of configuration and data management. The number of ships which currently have each system installed is contrasted to the number of ships anticipated to have the system installed in the 1980-85 time frame. The numbers in Fig 7 therefore represent maximum numbers in 1980 when a new computer system could be in operation at NSWSES and probable numbers for system deployment by 1985.

The large increase in the total number of systems deployed will not cause a direct one for one increase in the demands placed on the data management system since the Technical Data Department will have varying degrees of responsibility depending on the system. For example, the increase of 41 ships having Tartar capability will have more impact on the data management system than will the increase of 184 ships having Harpoon capability since the data for the Tartar will include the launching system, the fire control system and the weapon direction system where as the data for Harpoon will include only interface equipment. The large increase in the number of systems supported will, however, still be reflected in a significant increase in the data which must be stored and managed.

In addition to the increased volume of data required there will be a large increase in the number of users of the data since some systems will be deployed on a wide variety of ships where in the past the systems were largely confined to the surface missile fleet. For example, it is planned to install Nato Seasparrow on eleven auxiliaries and the Close-In-Weapons-System on 192 ships including several auxiliaries and support ships in addition to the surface missile fleet.

The increased fleet strength and proliferation of systems will also effect configuration management through the expanded requirements to incorporate new data into the data base from the fleet contractors. This area is particularily important for those new weapon systems which are planned due to the large input of initial data. In addition, a relatively large number of engineering changes will be required during the test and evaluation and early deployment stages for new systems. During this time period rapid response is required to make and document engineering changes. The deployment of new systems also requires a major effort in the development of proper parts support and the preparation of provisioning technical documentation.

System		Present	1980-1985
Terrier		34	30-35
Tartar		52	90-95
Talos		7	1-5
NATO Seasparrow		3	55-60
Harpoon		0	180-185
Close-in-Weapons-System		0	190-195
Point Defense		50	55-60
AEGIS		0	1-3
Anti-Ship-Missile-Defense		32	110-115
	Totals	181	712-753

Notes:
1. Land based sites and foreign ships are not included.

2. Number of ships with indicated capability is shown. Some of these ships will have multiple capability for a given system.

Figure 7 - CONFIGURATION MANAGED SYSTEMS

D. NEW RESPONSIBILITY AREAS

As discussed in previous chapters the responsibility of the Technical Data Department has expanded to include several diverse systems. Based on the increasing need for configuration management it seems likely that this trend will continue.

1. Search Radars

The department currently maintains the CIIF file for the SPS-58 search radar and tracks the location of several other search radars in the CSA site file. In the near future it is anticipated that the SPS-48 search radar will also be included in the CIIF file. There are currently 50 SPS-48 radar systems deployed which would cause a step increase on the data system demands followed by a more gradual expansion as more SPS-48 radars are deployed. The need for some source of configuration management of search radar systems will increase in the future as the complexity of the system increases and these systems become more closely integrated with the weapon systems.

2. Gun Fire Control Systems

The department is now involved in the configuration management of three gun fire control systems. This involvement resulted from the close coordination required when the MK-86 fire control system was undergoing test and evaluation at NSWSES and timely configuration changes had to be effected and documented. It is likely that additional GFCS will be incorporated in the future.

3. Underway Replenishment

The Commander Naval Surface Forces Pacific (COMSURFPAC) in April 1976 identified an urgent requirement for configuration control of underway replenishment (UNREP) equipment to the Naval Sea Systems Command. The exact form of configuration control to be used and the organization which will be tasked to establish configuration management of the UNREP equipment has not been decided. One configuration control system recommended by COMSURFPAC was the current ORDALT system. The engineers responsible for UNREP equipment are located at NSWSES and a logical choice to document and maintain configuration control is the configuration division at NSWSES. If the division were tasked with this responsibility using the current data management system, the accomplishment would be very slow and incremental due to the process for incorporating new data as described in Chapter II and the complete lack of configuration control which now exists on the UNREP ships. The addition of UNREP configuration responsibility would in the long run represent a significant increase in data storage requirements. This would almost surely lead to a degradation cf service to other users.

E. PREPARATION, ACQUISITION, AND RELEASE OF TECHNICAL DATA

As described in Chapter II the Data Management Division is responsible for all aspects of data procurement for systems under the station's cognizance. At the present time this acquistition process is tracked manually. The process could be followed much more efficiently with a computer based file similiar to the Class 1 Change file used to track Engineering Change Proposals. However, the difficulty of creating a new distinct file under the current data management system makes the automation of the process unattractive. If an integrated data base existed this data acquistiion process could readily be automated.

F. SUMMATION AND CONCLUSIONS

Throughout this chapter, the authors have eluded to a number of variables which will impact both the urgency of need for an automated system and the specific characteristics of that system. At this time it might be advisable to recapitulate these variables to consolidate the structure of the model which has been used for these predictions. Over the desigu, production, and installation phase of the system life cycle, these variables should be continually assessed to ensure that the end product will fulfill the requirements.

1. Navy Shipbuilding Program - physical size of the Fleet

2. System Development - number of systems maintained, number of system users

3. New Responsibility Areas - change in user needs, change in NSWSES cognizant systems, change in responsibility for systems currently managed only in part

4. NSWSES personnel manning levels - need for increased productivity

The total impact of the above variables on the problems identified in Chapter II must be considered by NSWSES in the justification for and the development of a modernized data management system. The variables which have been identified are general in nature. However, it is the opinion of the authors, based on the trend of these variables and the close observation of the operations at NSWSES that the need for a modernized data management system is indicated. It is recognized that before a formal request for a modernized system is uade, specific data must be gathered to support this general conclusion and to define the parameters of the system requested. It is felt that the specific data will support the need for a modernized system. The following chapter provides the basic system definition that the authors feel is required to fulfill NSWSES future requirements.

IV. SYSTEM CHARACTERISTICS

A. SYSTEM DEFINITION

The system specifications which will be formulated by NSWSES personnel must be based upon a clear definition of what the system must accomplish. This definition is an interaction of user needs and technological capabilities and as such must remain dynamic in character until final formulation of the specific equipment configuration has occurred. It is rooted in the variables described in Chapter III and, therefore, must remain general enough to respond to their change but must be specific enough so that a dialoge exists to facilitate technology response to the need.

To initiate this process, the authors will start the first iteration by offering a general system definition and extracting from it the general areas of technology that might apply. Section IVC will represent the intial interface with technology in the form of a review in the areas of interest. Section IVD will be a return to the definition to appraise the impact of this technological review.

First, the system required must marry the functions of data and configuration management. The elements and interrelationships of these two areas support the concept of an integrated data base accessable by all users. To facilitate this, some type of computer system will be needed with the capability of quick response to inquiries and ease of updating and inserting data. These considerations would indicate that the system should be on-line vise batch in nature. This requirement can be fulfilled in two ways: 1) a large computer where NSWSES personnel would be tenants in a multiprocessing system or 2) a minicomputer maintained by the station and specifically dedicated to ICMDS. If the system were merely an ADP operation with easily definable input and output data requirements, the first option might seem satisfactory. But the requirements of NSWSES are not only data processing but interactive control between analog devices which must perform operations in various output media (eg. microfilm production). This need all but eliminates the simple owner-tenant relationship and therefore, the authors will concentrate on the second option of having a dedicated data handling device such as a minicomputer. This defines the first area of tecnological review.

The major output of the configuration management branch, other than hard copy reports, is microfilm packages which are used by both shipyard and Fleet personnel. These are produced from the aperature cards that are filed in the AACF. The bulk of the AACF has been previously discussed as a critical factor in the time required for distribution of microfilm packages. A technology that has emerged in recent years is the process of converting engineering drawings to a digital format and storing the information on magnetic tape or disk. If feasible, this process would allow computer controlled microfilm production and significantly reduce the physical storage requirements of the AACF as well as the number of personnel required to maintain it. It would also facilitate the acquisition of drawings in digital form and reduce the amount of hard copy.

Inherent to the concept of digital storage of drawings is the capability of projecting the drawing on a CRT input/output (I/O) device for the use of engineering codes and quality assurance personnel. This would allow engineering personnel to query the CIIF for the latest revision of the drawing needed and call the display from a terminal. Once the section of interest is displayed, hard copy could be produced if required.

A follow-on to display of digitally stored drawings is the concept of automatic drafting. If a drawing is to be revised by station personnel, the process might be done by a computer controlled drafting system with preprogrammed standard functions. This would allow drawing updates to occur within a mater of minutes instead of the 24 man-hours now estimated.

The authors have defined a multipurpose, multiprocessing computer system by functional areas. The issue of support equipment should now be addressed as it will ultimately impact the actual configuration of the system. The computer system includes two additional considerations: 1) the type of I/O devices required and 2) the storage facilities. The type of I/O device will vary between functional areas. The terminals required by data and configuration managers will differ from those required by engineering codes because the need to display/change engineering drawings is not present. Therefore, a review of the "intelligent" terminal technology is in order.

Because of the possibility for digital drawing conversion, the total storage requirements for the system may become quite large. The actual size will depend upon the portion of the AACF that will be digitized. The issue of storage devices becomes a tradeoff between mass storage systems with a small amount of operator interaction and convential disk and tape storage with the operator drawing the file from a library system and mounting it as required. The overriding consideration in making this tradeoff will be that of system access time.

The preceeding section included a general definition of the system characteristics and derived the areas of technology in which to start the initial review. This relationship is summarized as follows:

1. Central Processor - Minicomputer

2. Automated Microfilm Packages - Computer- Output-Microfilm (COM)

3. Retrieval and revision of engineering drawings - Digital Storage of Drawings, Automated Drafting

4. Support Equipment - "Intelligent" Terminals, Mass Storage Devices

B. TECHNOLOGICAL SURVEY

The following section will provide an initial survey of the specific technologies addressed in the system definition. It was the authors' impression that mention of specific brand names should be kept to a minimum so that the survey would not result in a biased representation, reflecting our own impression of what systems are superior/inferior. As the survey proceeded, it was found that in some cases, a particular approach was best exemplified by a specific manufacturer. In the following presentation a number of manufacturers are listed but only by suggesting the characteristics of their systems as they pertain to the areas of interest.

1. Minicomputers

Minicomputers first became an important part of the computer community about 1965. With essentially no sales in that year, the minicomputer industry had grown to over $300 million annual sales by 1973, and continues to grow at a rate of 20 percent to 30 percent per year. Unfortuneately, as in any study of a particular "industry", accurate figures are difficult to estimate due to lack of a precise definition of the "industry" per se. DATAPRO REPORTS for that same year (1973) estimated worldwide market volume for U.S. minicomputer manufacturers to range from $350 million to $500 million a year. These figures included marketed peripheral equipment and software. Minicomputer mainframes alone were believed to account for $100 -$125 million.

Though total sales figures may vary significantly, minicomputers still represent only a small portion of the $13 billion total market in the United States for computer products and services. Nevertheless, the minicomputer segment is expected to continue its rapid growth with estimates of worldwide computer market volume soon to reach an even $1 billion.

As for manufacturing firms, Digital Equipment Corporation, the company that started the minicomputer boom in the mid-sixties with the highly successful PDP-8 line, is still undisputed king of the minicomputer field. DEC has delivered more than 26,000 computers to date and still commands roughly 30 percent of the minicomputer market. Rounding out the "big six" among the minicomputer builders are Honeywell, Hewlett Packard, Varian, Data General, and Microdata.

The second rank of minicomputer makers comprises the aggressive, innovative young companies such as Computer Automation, Digital Computer Controls, General Automation, and Interdata. Minicomputers are also being built by divisions of well established conglomerates such as General Telephone and Electronics, Lockheed, Raytheon, Texas Instruments, and Westinghouse. There are also dozens of comparitively small, and as yet unproven, companies whose survival will depend upon their ability to back up their imaginative hardware ideas with effective marketing, production, software and customer support.

As might be expected, IBM gets a category unto itself. The undisputed leader in most other segments of the computer field is still playing a comparatively minor role in the minicomputer field. Seemingly to cage its bets, IBM waited until October 1970 to introduce its System/7 and even then maintained a low profile. In January 1975, however, the giant began to show serious signs of life and took the business end of the miniconputer industry by storm with the introduction of its System/32. Its very latest entry, System 5100, will undoubtably aid in giving IBM a large percentage of an industry it heretofore chose to neglect.

In all, more than 80 companies are now marketing minicomputers in the United States. The current offerings of these companies include more than 200 minicomputer models.

Initially minicomputers were used almost exclusively for scientific and analytical applications; now they are widely used in industrial, business, and commercial environments. As described above, this has produced a dramatic shift in the sales profiles for these machines. No longer are research laboratories, universities, and hospitals the sole hunting grounds for minicomputer salesmen. Their products are now being demanded to satisfy many different applications as evidenced by the following list:

1. Electronic and mechanical engineering design
2. Land, sea, and air navigation
3. Telecommunication control
4. Message switching
5. Automatic warehousing
6. Process and production sequence control
7. Automatic typesetting in the printing industry
8. Machine tool control
9. Continuous industrial process and quality control
10. Business accounting and information systems
11. On line data acquisition
12. Performance logging in nuclear and power stations
13. Computer peripheral control
14. Data concentration for communication and remote-batch operating systems
15. Data collection and recording
16. Data preparation systems for large-scale computer information systems
17. Telemetry systems for control of general utilities such as gas, electricity and water supplies
18. Computer-aided instruction in the field of education

The above list, by no means complete, serves to give an indication of the areas of activity that do now, and will increasingly in the future, utilize minicomputer resources.

The following basic trends appear to be emerging:

-The minicomputer is increasingly becoming part of a much larger hardware, instrumentation, and control system.

-The serious computer manufacturers are gearing their design and marketing strategies to selling to original equipment manufacturers, as well as systems houses, large scale computer manufacturers, communication companies and the myriad of both large and small business enterprises.

-The potential user has a far wider choice available, is much more cost-concious than past users, is more aware of the additional requirements of minicomputer systems and is both willing and able to start small in an effort to grow large.

-Prices will continue to fall as a result of technological improvements and aggressive competition. These fundamental points are the result of the following changes:

1. The reduction of processor and memory costs.

2. The greatly increased reliability and flexibility now available.

3. The increased availability of operating, application, and support software.

4. The increase in the use of read-only memory and microprogramming.

5. The great improvement in hardware and software design.

6. The considerable increase in the experience gained by using minicomputers successfully in a range of applications.

2. Computer-Output-Microfilm (COM)

Computer-Output-Microfilm is an information system that converts computer data into readable form on microfilm. The COM process is direct, quick, and convenient. It significantly reduces the time and expense of moving a computer's results into a form suitable for human use. This interaction of microfilm technology with data processing systems has opened new vistas in the design and operation of modern information systems.

COM first appeared commercially in 1959 by such companies as Stromberg DatagraphiX, IBM, Eastman Kodak and Data Display Incorporated. These devices were mainly CRT printer-plotters intended for administrative and engineering applications. But their marketability was uncertain and shortly IBM left the field and has never returned.

COM is a microfilm camera backed up to a computer. In its most basic operation, a COM system takes the digital signals recorded on magnetic tape or coming directly from a computer system, runs them through a logic section to determine their locations, converts the signals into an electronic beam and projects it onto a cathode ray tube (CRT) screen. A special camera then takes a picture of the CRT screen at specific intervals and records the contents on film.

COM recorders have been produced that operate both on-line and off-line from the host computer. On-line COM devices are connected directly into a speed paper printer. Because of this, no modification of the host computer's program is generally required when an on-line COM recorder is used. Off-line COM systems receive the computer output on magnetic tape. On-line COM recorders might be somewhat cheaper, since they do not include an input tape drive. However, the off-line method offers more compensating advantages:

1. The increased speed in transferring data directly to magnetic tape instead of a COM recorder significantly reduces computer time and expense.

2. If the COM device is incapable of high speed operation, then the on-line arrangement usually will only serve to slow down the internal performance of the computer system.

3. Reruns of the COM operation do not require computer time.

4. A number of microfiche titling and indexing techniques that are commonly employed with off-line systems are impractical with on-line COM.

a. Transfer Techniques

There are bacically four technologies for transferring data to microfilm: cathode ray tubes (CRT), electron beam recorders (EBR), laser beam recorders (LBR), or light-emitting diodes (LED).

The CRT technique is the oldest and most commonly used method for COM recording. An electron beam draws the desired characters on the face of the CRT. The image of the character passes through a semi-reflective mirror and lens system onto the unexposed film. After a page is exposed to the film, the film is advanced, and the next page of information is displayed on the face of the CRT. If desired, the image of the form used when generating the report on a computer high-speed paper printer can be superimposed on the film. This is accomplished by flashing a bright light behind a glass or film slide on which the image of the form has been photographically reproduced. Through the use of a reflective (semi) morror, the form's image passes through the lens system onto the film. An alternate technique involves the use of a programmed merge, and requires the drawing of the form around the data on the face of the CRT by the electron beam.

EBR, unlike the CRT technique, writes directly onto the unexposed film with the electron beam. To properly control the direction of the electron beam, this process must be performed in a vacuum chamber. Unexposed film is drawn into the chamber, and a page of information is written onto the film. After the page has been completed, the film in incremented, and the next page generated. With the EBR technique, if a form slide is desired, its image is placed on the film by the use of a second lens system after the data has been written on the film. One of the main advantages of the EBR technique is that a special type silver film can be developed by heat rather than wet chemical processing.

LBR writes directly on dry silver microfilm forming a latent image that is developed by heat, not chemicals. The laser is expanded through a beam-expanding telescope. Then, it is deflected through an acousto-optic modulator to form seven beams which write at high speeds directly on the film.

The LED technique directs its digital signals to a bank of light-emitting diodes through a character translation matrix. Light from these diodes is tramsmitted through fiber optic strands to form an image. An entire line is thus formed, displayed, and photographed via the fiber optics assembly. The film is then advanced one line at a time. The forms overlay process is accomplished by use of a second lens system, as used in the EBR system. LED has two limitations: 1) in the microfiche production, there is difficulty in controlling the movement of the film and 2) because LED emit red light, red-sensitive film must be employed with special filtering processes producing a less sensitive process with inferior resolution than blue-light sensitive processes.

b. Film Types

There are four types of film utilized in the COM process. The majority of the industry has chosen the silver halide film for making the master copy; the most popular brand is the Kodak Dacomatic. The silver halide film is known for its inherently wide tonal range and its contrast range satisfies most specifications. In addition, a silver halide film specimen has been known to last over 50 years without showing signs of deterioration, an important characteristic for archival mediums. This type of film produces a negative or reversal image. There are, however, several limitations. Most annoying is their requirement for wet chemical processing, evolving several baths and roller devices. This type of film is also subject to easy scratching. Finally, the price of these films is quite high.

Diazo film is much less expensive than silver halide film and is used widely for microfilm duplicating. The film contains dyes which produce a visable image when exposed to ammonia vapors and a strong ultraviolet light. Unlike silver film, diazo film is non-reversing. Its cost is low and it gives a highly satisfactory duplication with excellent contrast. It does have the drawback that ammomia vapors require special ventilation and create an unpleasant working situation.

Vesicular film is a comparatively recent development which is competing hard against diazo. Transparent crystalline particles are mixed with a transparent resinous plastic and coated onto a mylar base. When exposed to ultraviolet radiation, these crystallites change to nitrogen gas. To develope the image, heat is applied. The nitrogen gas pockets expand, with small bubbles created, which form the image viewed by the user. When the film is exposed to ultraviolet radiation, the remaining crystallites form nitrogen which diffuses away. The process is reversing. The finished vesicular copy is very sturdy and scratch resistent. A disadvantage is that if the exposure to ultraviolet light in the duplicating process is not sufficiently prolonged, the images will tend to darken over a period of time.

Dry silver film is a 3M product used on the 3M EBR and LBR COM. A latent image is formed by the electron or laser beam writing directly on the film, and then developed by heat, not chemicals.

c. COM Hardware

Some of the more expensive COM recorders have built-in minicomputers to control their operations. The primary function of this internal computer is generally to reformat the input data prior to recording on microfilm. By utilizing this technique, the mainframe computer is relieved from the task of reformating and coding by means of subroutine modifications to the operating system or restricting the COM's use by using hardware devices in the COM to make it appear to the computer as an on-line printer. These minicomputers are frequently supplied by minicomputer manufacturers with proven experience in that area. Minicomputers are mostly used in graphic applications or when special instructions are required for titling and indexing the fiche.

There are other pieces of equipment involved in COM systems. These include:

1. Magnetic Tape Unit - Most COM systems include in their purchase price a magnetic tape unit for input into the system. The Memorex 1603 appears to be the only system currently available that does not. Stromberg DatagraphiX models 4200 and 4520 were previously marketed without a tape drive included, but these have been withdrawn from production. The majority of the tape drives accept 7 or 9 track tape at 556, 800 or 1600 BPIF.

2. Microfilm Processors - With the exception of the 3M Dry Silver Film, all COM original film requires some "wet" chemical processing. This process can be accomplished either through the use of a separate film processor or, as in the case of the Quantor Model 105 COM Recorder/Processor amd NCR Model 643 Microfiche Recorder/Processor, through the use of an internal processor. The 3M Dry Silver Film does not require a wet process but is developed via an internal heat process, and therefore a separate processor is not required.

3. Microfilm Duplicator - In order to make mutiple copies of the microfiche or microfilm for distribution, a microfilm duplicator is required. A variety of models are available from the DatagraphiX Model 71 table-top unit which operates at 360 fiche per hour, to their Model 75, which has a through-put speed in excess of 1000 copies an hour and which collate up to 100 sets automatically.

4. Microfilm Readers/Printers - One of the most important and yet often overlooked piece of equipment in any COM installation is the microfilm reader/printer. There are many styles and types of readers and their price range varies from $175 to $400 for microfiche. Microfilm readers are more complex and range from $400 to $1750. A survey conducted by IEEE SPECTRUM magazine revealed that the majority of readers function quite satisfactorily. The only complaints were concerning the portable models problems with illumination and optical distortion. Reader/Printers give the added advantage of being able to produce a hard copy of the page desired on a selective basis.

5. Automatic Retrieval Devices - Devices are available to permit the selection and insertion of a fiche into a fiche reader in a matter of seconds. The major advantage of using this type of device is the speed and simplicity of accessing large amounts of information. The major disadvantages include the cost of the retrieval devices and the additional fiche production time required to prepare the fiche for insertion into the reader.

d. Other Considerations

In addition to the physical specifications of COM equipment, there are a number of other considerations which must be weighed prior to purchase:

1. A clear understanding of the requirements and the exact output functions expected to be derived from the COM system, is of the utmost importance.

2. These factors should be analyzed: data file size, frequency of update (should be no more than once a day), need for hard copy, number of locations requiring

copies of reports, and the retrieval requirements.

3. Based on these requirements, the current market capabilities should be reviewed and the decision made based on these requirements as to whether the COM system will be on-line or off-line. This will be based in part on software capabilities of the various systems and their hard-wired functions. Along with this decision, the requirement for a minicomputer must be analyzed, remembering that the most sophisticated approach is not always the best.

4. Costs for utilizing COM equipment - data preparation, microfilm readers, supplies should be included to redesign the total information system.

5. Finally, an analysis should be made of this total cost per line of copy, the timeliness of the information, convenience and availability of output.

e. Future Trends

The industry is experiencing incredible growth. A survey conducted by International Data Corporation determined that as a result of the 40 to 50% increase in paper prices in the last two years, 42% of those computer sites surveyed were considering COM implementation. From this, they determined that the COM industry would double in the next five years.

As far as technical improvements, the "Ultrafisch" has great promise. Also called Photochromatic Microimage (PCMI) Technology, ultrafiche is a result of a very fine grain film coupled with improved optics, giving a high density fiche on the order of 96X reduction. But more important is the characteristic that photochromic material can reverse color based on temperature or specific radiant energy. As a result, the image can be changed (in contrast to the silver halide film), producing a perfect master at less cost and time delay. This will be particularly applicable to graphic requirements. Ultrafiche is limited because it requires careful balance of quality control, sensitive readout equipment and high volume.

Another innovative technique is Computer- Input-Microfilm (CIM), which is a scanning technique in which the image on microfilm is scanned and stored as computer records. Such systems have most commonly been applied to engineering development applications and are not widespread at this time.

Currently, there is a trend toward front-end processors because of their flexibility. There also is a trend toward the installation of a second and third COM unit at many existing COM installations. But, price will probably not decline, and even may increase due to a greater sophistication and an inflated economy.

3. <u>Digitalized Drawings and Automatic Drafting</u>

One of the rapidly developing areas of computer technology is the storage of engineering data in digital format. The digital storage of an engineering drawing offers several advantages over the current practice of utilizing hard copy for the design, engineering and manufacturing functions. These advantages include:

1. Automated drafting systems which greatly reduce the time required to create or change an engineering drawing.

2. Vastly reduced storage space required for

historical files.

3. The ability to reproduce any number of consistently clear and accurate drawing copies.

4. The ability to interchange information in tape or disk form without resorting to hard copy.

5. Numerical control of the manufacturing process.

6. The digital data can be output to hard copy, microfilm or CRT for display or interactive operations.

7. The data base is easily maintained through interactive terminals.

8. A product can be completely developed from design through manufacturing utilizing only digital data and never having hard copy of the engineering data.

One problem which still exists with digitilized storage of drawings is the slow rate at which current hard copy can be converted into digital format. The data base is very versatile once created but building a large data base is very time consuming.

a. The Designer System

The Computervision Corporation Designer System is described below to provide an example of the application of current technology in interactive graphics.

The Designer System is a complete automated system that can integrate a development effort from the first design idea to the finished product. The engineer and designer interact with the system through CRT devices or plotting surfaces. The system provides computer aided design and production.

The Designer System offers an autoscan operation which can input data from hard copy at approximately four square inches per second. This is an improvement over the manual digitizing process which requires that each point and line of a drawing be defined manually. However, this rate is still relatively slow when massive amounts of data must be input to the system.

The Designer System offers interactive plotting surfaces which allow drawings to be digitized into the system or plotted out on the surface. In addition the system provides interactive CRT terminals with two or three dimensional displays.

The central processor for the Designer System is a high speed, general purpose minicomputer with up to 128 K 16-bit words of main memory, supported by cassette tape, magnetic tape, disk memories of up to 14 million word capacity. A single central processor can typically control four or five interactive terminals.

Once the digital data base has been created, all of the advantages previously mentioned are available providing a very versatile real time system.

The entire segment of interactive graphics is still in the very early stages of technological development. Because of the many and important advantages which digitally stored engineering drawings have over hard copy or film, it is almost certain that many companies will go to digital engineering data bases to realize the economic advantage which will result. It is very likely that the government will also develope systems which utilize digital drawings, making interchange of engineering drawings in digital format is entirely possible. The automated drafting function is well developed today and is operational in several companies. Refinements to the automated drafting systems can be expected over the next few years.

4. Mass Memory Systems

The need for mass memory systems in the range of 10^{12} bits has become evident with the advent of increasing dependence on computer information management systems in business and scientific endeavors. The ideal system, allowing random access of 1 usec with a reasonable price, has not yet been realized even though promised by one manufacturer as long ago as 1971. Presently, non-random access systems are available which provide for mass storage at a reasonable cost per bit.

While moveable head magnetic disks offer access time advantages, even the latest IBM-3330-11 (2000 Mbyte capacity) disk does not lend itself to mass storage application. Magnetic recording techniques on tape have produced densities of $1.28X10^5$ bits per inch which for 10^{12} bits would require $7.8X10^6$ or nearly 8 million square inches of standard tape. The primary constraint is the physical limitation of head alignment and the necessary decrease in distance between head and tape for higher densities. Increased effort in overcoming these mechanical problems has had limited success resulting in the elimination of this method from consideration in mass memory systems.

a. UNICON

Precision Instruments manufactures the UNICON 690-212 which permanently stores data utilizing laser technology to burn a hole in a metallic medium to represent a "1" and the absence of a hole to represent a "0". The intensity of the beam is reduced during the "read" cycle and the reflected light is monitored. The "data strip" recording media is a 31.25"X4.75" polyester base coated with rhodium. Each strip contains approximately 11,440 tracks for a total capacity of $1.6X10^9$ bits per data strip. There are 25 strips per pack and 18 packs per carousel for a total capacity of $0.7X10^{12}$ bits.

There is one carousel per system, horizontally rotated between two read/record units contained in the laser recorder unit. Each read/record unit is independent, which provides for simultaneous read/write capability. Each unit consists of a drum for locating a particular data strip, a mechanism for transfer of each strip from the carousel to the strip drum, and a laser beam track select unit which physically directs the laser beam deflection mechanism to focus the beam to the proper track for reading or writing. This process takes approximately 10 seconds after which a data transfer rate of $3.4X10^6$ bits per second is possible. The interface with the host computer is accomplished in the Recorder Control Unit (RCU) which uses a minicomputer to provide overall control of the memory system.

To provide for simultaneous read/write operation, there are two independent interface systems consisting of a staging disk, core buffer, word processor, read/write and error subsystems, and switching units. The word processcr contains the software interface and is loaded and monitored by the minicomputer to control the laser recorder unit and switching data flow to the core buffer and finally to the staging disks.

b. GRUMMAN

Using technology originally developed for spacecraft tape recorders, Grumman has provided 16 channels of 8000 bits along each inch of half inch wide, 260 foot long tape. Housed in a cartridge approximately 6X3 inches, each 260 foot tape has a capacity of about 3.56×10^8 bits. The tape is always positioned at midpoint when idle for faster access to a particular file. Eleven cartridges make up the basic module (pac) which is one quadrant of a wheel or drive "reminisent of Kodak's Carousel slide magazine." A total of eight such carousels mount on one spindle to form 128 billion bit storage unit. Eight storage units are controlled by a masstape controller (minicomputer) to allow storage of 10^{12} bits. The system provides for allocation of up to 16 active files with a burst transfer rate of 10^6 bytes per second. A random search can be completed in an average of less than six seconds. The system was initially designed to interface with the IBM-360 and 370 but software for several other systems including UNIVAC and CDC soon followed.

c. AMPEX

AMPEX has introduced the Tera Bit Memory (TBM) system which boasts one of the largest capacity figures of 3.1×10^{12} bits. Reasonable access times are provided by use of video recording techniques which allow search speeds of 1000 ips and up to 6 simultaneous searches or the equivalent of 60 conventional computer tapes per second.

The system is functionally divided into two parts: 1) the Communications and Control Section (CCS) and 2) the System Control Processor (SCP).

The control section consists of the System Control Processor (SCP), External Data Channel Processor (EDCP), disks and channel switching hardware. The SCP controls overall functioning of the TBM system by processing requests of the host computer. It allocates transport modules, drivers, data channels, and disk space necessary to complete each request.

The EDCP acts as an interface between TBM and disks shared with the host computer. At least three core buffers with 16 Kbytes capacity each must be employed with a PDP-11 for continuous data flow from TBM to host. One staging disk can load as many as 800 TBM blocks of data of 130 Kbytes each. The type EDCP utilized constrains the data throughput.

The Data Storage Section consists of 1 to 6 transport drivers, 1 to 32 transport modules each with 2 topplates, and 1 to 3 data channels. Data only passes to the transport modules and never through the drivers. Switching allows any of the 6 drivers to be connected to any of the 64 toppplates and then to either the read or write portion of 1 of the 3 data channels.

The system may be expanded to maximum capacity and performance by adding up to 31 dual transport modules and 5 transport drivers to the base system. An intermediate number may be selected to suit any particular application requirements. With added data channels and another EDCP, 2 simultaneous read/write commands may be executed for a maximum .1.5 Mbytes throughput. The originally proposed system was to have 4.5 Mbytes throughput but was constrained by the computer capacity selected for the EDCP.

A summary chart of these three systems and a conventional comparison is shown in Fig 8.

	UNICON	TBM	MASSTAPE	Conventional Disk
System Cost	$1.6Million	$3.25Million	$3Million	$200,000
Throughput (Bits/Sec)	$3.4X10^6$	$1.5X10^{6}$*	10^6	$6.4X10^6$
Capacity (Bits)	$.7X10^{12}$	$3.2X10^{12}$	10^{12}	10^9
Cost/Bit (Cents)	$2.29X10^{-4}$	$1.016X10^{-4}$	$3X10^{-4}$	$2X10^{-2}$
Average Access Time (Seconds)	10	13.3	6	.075

*Function of EDCP selected

Figure 8 - MASS STORAGE COMPARISON

d. Filing and Transfer Methods

Most systems are designed primarily for what is termed "basically sequentially access" utilizing large data blocks. This significantly reduces efficient random access to a relatively small data set. The recording media is "control software" subdivided into "allocation units". Physical storage space is made up of an aggregation of allocation units. Selection of the size of the allocation unit is a compromise between space and processing efficiency and is also a function of the intended user application. Increased random accessing, even though slow at best, would imply larger unit size. However, up to 33% of storage capacity may be unused due to average user data block size. In the Grumman Masstape System, for instance, an allocation unit size of 1500 Kbytes allows an average access time of less than a second but with only 67% space utilization for a 1 Mbyte file size. For 131 Kbytes per unit space, utilization is improved to 93% but average access time is increased to approximately 6 seconds. Since even the best access times are too slow for numerous random access requirements, most manufacturers use compromise allocation units of approximately 130 Kbytes.

User files can be transferred from the mass media either directly or by staging. The direct transfer mode of operation requires allocation of a data path for each active file to each host, whereas, staged transfer requires only one data path for all files. Additionally, that path must remain dedicated during processing execution and the file must necessarily be processed sequentially. While staging requires host or shared hardware, after the file has been staged it may be randomly processed if the file has been staged in its entirety. Again, particular software must be tailored for individual requirements.

Selection of a particular file processing technique must include consideration of the file activity ratio. Very low activity ratio files would favor direct access. High activity ratios would indicate a batched input and sequential access. The latter is envisioned as the most prominent mode of operation.

e. Disadvantages

One of the disadvantages of mass storage systems is their high expense; although this is not the primary obstacle to their widespread use. For instance, Aetna recently installed a conventional on-line system with a capacity of only 1.24×10^{11} bits. Their system includes two, 3 Mbyte IBM-370/168 computers and 78 IBM 3330-11 disk units each with a 200 Mbyte capacity. Even a conservative estimate for the cost of the 370's is $3 to $4 million. The 3330-11's are $67,860 each, and the controllers slightly more. Therefore, the comparative prices of the mass memory systems cannot be considered a prohibitive factor.

A more substantial problem is the uncertainty involved with any new and untried system. Numerous technical problems can be expected in any initial implementation process, but especially in the instance of a configuration as complicated as mass storage systems. If substantial system tailoring is required for individual users, as with the first TBM customer, this problem is even larger as learning curve benefits are a less positive factor.

Systems such as UNICON which utilize non-erasable, laser recording tecnhniques certainly provide an excellent archival media, but are less flexible for numerous record processing changes. In research related to their own application developments, Ampex has found that after a file has been inactive for three months the probability is less than .5% that it will again be accessed. This is quite different from the NSWSES operation where conversations with personnel working with the AACF indicate that 95% of the cards are accessed in 5 years, 75% in 2 years, 50% in 1 year and 20% in 3 months. This would indicate a significantly more active system and possibly result in a greater man-hour cost savings if automated.

Probably the most significant obstacle to widespread utilization of mass storage systems is the excessive random access time. While direct access of pre-staged data helps alleviate the problem to some extent, the requirement to transfer very large blocks of data to access a single relatively small individual file results in further inefficiency. This narrows the practical application of mass memory systems considerably.

Finally, the pay-off for conversion to a mass storage system does not occur for at least five years, which leads to the very real risk that technological improvements will render the system obsolete and reduce the returns of a sizable capital investment.

f. Advantages

There are a number of positive factors characterizing mass memory systems. They offer obvious economic advantages in cost per bit as compared to conventional methods of on-line storage. Additionally, they feature hands-off data retrieval, relieving many scheduling and librarian costs/problems and security against data loss and overwrite risks inherent to the often piecemeal conventional library techniques. Many utility functions may be accomplished with some systems in an off-line mode or independent of the host computer. The physical size reduction of mass storage facilities over conventional systems for a given storage requirement essentially eliminates the requirement for bulky off-line tape libraries. The modular add-on design of most systems allows for capacity/performance changes as requirements change. Finally, the data throughput rates are comparable to conventional storage media making them quite competitive in sequential processing applications.

g. Future Mass Storage

In this area there are almost as many predictions as there are predictors, but a representative sample is offered here.

Charge coupled devices utilize much the same technology as MOS devices, but remain unattractive for mass memory applications due to their volatile storage process despite many desireable features (e.g. fast access times).

Magnetic bubble devices have essentially been three years from production for the past five years. Using present technology they too are relatively volatile in that a small D.C. voltage must be maintained. However, RAND Corporation predicts that by 1980 bubble technology advances will result in a non-volatile system with a 2 usec random access time and a density figure of 10^6 bits/in^3 for 0.01 cents/bit. This is still not sufficient for mass memory requirements as 6.94×10^3 ft^3 would be required for storage of 10^{12} bits but for lesser storage requirements it presents a viable alternative.

Electro-optical techniques encompasses both electron-beam and laser technology, as well as several radiation sensitive media (ie. thermoplastics and photochromic materials). Electron beams can be focused for extremely high potential density rates, but must operate in a high vacuum which limits their application possibilities. Laser beams can operate in normal environments and can be focused with several mechanical and non-mechanical means. Electro-optical techniques involve an analog signal which drives an electro-optical modulator which varies the intensity of an argon laser.

Holograpqic techniques entail the recording of optical wavefronts formed by the interaction of a reference laser beam with a second reflected beam. In erasable media heating above curie temperatures and a magnetic field can be applied in 15 to 20 nsec, but upwards of 100 kwatts of power is required. An entire page of data could be recorded simultaneously further speeding the process. Reading is accomplished by illuminating the recording with a light beam and reflecting the light on an array of photo conductors. Time required is less than 10 usec.

The most far reaching predictions come in the area of laser applications. For instance, Laser Computer predicted a system utilizing a 4X4 foot thin film plane with a capacity of 10^{13} bits with a maximum access time of 20 nanosec and a transfer rate of 50 Mbits/sec. The cost was to be $2X10^{-5}$ cents/bit. Further characteristics were non-volatibility for greater than 25 years, less than one error per 10^{9} bits, associative memory organization, no moving parts, plug-in capability with IBM peripheral equipment, and with a price of less than $1.2 million. Phenomenal predictions such as systems with capacities of 10^{40} bits have been forthcoming from the same source. These systems are to feature access to 1000 bits in less than .3 nanosec. Unfortunately, very few specific details of any significance have been forthcoming since the initial announcements. Furthermore, a few calculations indicate even with the speeds predicted, a total of 10^{21} years would be necessary to access all the memory in the 10^{40} bit capacity system.

While such announcements are rather over-optimistic and deserving of skepticism, predictions by numerous credible authorities have been extremely encouraging. For instance, by 1983 another predictor asserts that a moderate speed device utilizing a disk with holographic or cryogenic technology will have up to 10^{14} bits/unit capacity, an access time from .01 to 100 msec, and a price of $6X10^{-6}$ cents/bit. Still other more skeptical individuals predict present motion of media techniques will be necessary for the forseeable future. Current mass memory systems require motion of the media past a read/write device due to the present recording density technology. Therefore, access time is relatively poor which essentially negates the practicality of random access processing. This results in many users with relatively large storage requirements such as Aetna using conventional storage devices at a considerably higher cost/bit.

h. Summary

While mass storage systems are useful for archival means, that characteristic is not an important selling point in most instances. The application of these systems is relegated generally to batched input and sequential file processing in applications which require a large data base (greater than 10^{11} bits) on line. Furthermore, they would normally supplement conventional devices as part of hierarchial system rather than replace conventional equipment entirely.

Numerous problems were expected in initial installations and indeed they materialized in most cases. Most mass storage manufacturers conceded the system would be difficult to sell from the beginning. One executive was quoted, "While it should appeal to companies with massive tape-handling operations, the very size of such operations makes managements hesitant to make radical changes". Nevertheless, when the first systems were available in 1971, a market research firm (Quantum Science Corporation) predicted a $100 million market by 1975. This has not materialized. Again, definite figures are very difficult to obtain, but it is extremely unlikely that any one vendor has sold more than 12 units in the past five years. At least one manufacturer has apparently met with almost total failure in establishing a market. Another, however, is openly optimistic that initial problems have been overcome and predict increased future sales.

Future technological breakthroughs in developing fast access, high density storage media are a certainty. It may be a non-moving media device as is envisioned by Laser Computer Corporation or a disk type system as envisioned by more moderate predictors. Even if all the technical problems had been solved, the largest risk factor would be whether or not a potential buyer can expect to reach their pay-off before a quantum technological breakthrough renders their entire hierarchial system obsolete.

5. Intelligent Terminals

On-line computing systems are designed to use terminals and telecommunications links to overcome the limitations of batch processing systems. Strategically, a terminal can be considered as a device which has one or more of three functions. First, it may be an interactive device which enables the user to communicate with a computing system at a record level, rather than at a file level. Secondly, it may be a device which transmits and receives batches of data quickly and accurately to and from a computer. Thus it overcomes the problem of remoteness. Thirdly, it may be a device which has intelligence of its own and is able to perform certain tasks itself, thereby releiving the main computer and reducing the load on the transmission line. Any type of terminal may be provided with some level of intelligence.

The benefits of relieving the main computer are that the computer is better able to give fast response to messages which need a fast response, is better able to handle peak loads, and is freed to do other work. As a consequence, costly storage additions to the central computer can be averted. The benefits of reducing the load on the transmission line are that less errors will occur and that transmission costs may be reduced.

An intelligent terminal generally consist of the following:

a. The components of an interactive terminal: a means for inputting data (now nearly always a keyboard), electronics to code and format the data, communications circuitry, and a means for presenting data to the operator (CRT or teleprinter).

b. A processing unit capable of executing conventional computer instructions, for formatting and editing the input data, detecting errors, generating check sums, etc., and controlling the functions of the operator.

c. High speed memory for storage of both data and operational programs. A new program can be read into the terminal from an external storage unit or via the modem interface from a computer. The program can be read into the terminal under the control of a permanent program held in a ROM. The program which is read in can be entered into programmable read only memory (PROM) area where it cannot be altered. On some terminals, a board containing logic circuits can be unplugged and replaced by another.

d. Mass storage, typically cassette or cartridge tape, and conventional or floppy disks, can be used both for data and program storage.

Compared with equipment which would have had the same capability of just a decade earlier, an intelligent terminal is incredibly small in size, reliable to use, easy to maintain and, when necessary, to repair; most of all though, it is easy to use, because it can be programmed to provide different levels of man/machine dialogues depending on the application and the person using it.

In general, there are three major reasons for putting intelligence in a terminal: 1) for communication, 2) for bulk memory control, and 3) for operator assistance.

Terminal aide for the operator interaction provide: 1) local editing of entered data with page buffering, and 2) fill-in-the-blanks screen format. Fill-in-the-blanks allows the operator to use the processor capabilities to display blank screen formats to assist the operator in a data entry operation by providing visually assisted guides.

Intelligent terminals can check and validate data prior to transmission. It can pull information off local storage, upgrade it and use it as required. Again, on an as-required basis, information will be transmitted to the centralized computer, the checking and validation will have already been done and the computer can be used for its main purpose, which is generally processing data in large amounts.

The intelligent terminal is essentially a single key-entry station which has the capability to support various peripheral devices including random access devices being used concurrently with data entry. This ability fulfills the needs of a remote site with limited data entry requirements. However, when a large number of key entry devices are required at a single site, the cost of intelligence needs careful analysis. If these terminals will require sharing of files for inquiry/response or for current information, then the cost of intelligence would be unnecessary. In addition the cost of unshareable peripheral devices such as magnetic tape drives, card readers, printers, and communications on a single display intelligent terminal limits the practicality of having multiple intelligent terminals at one remote site.

To overcome these disadvantages, some vendors have incorporated the concepts of intelligent terminals in clustered versions. In these systems each display can perform as an independent intelligent terminal with respect to user-programmed data entry. Multitasking software allows data entry to run concurrent with processing and communication. Using such a system an organization may tailor the elements of its distributed processing network to fit the throughput requirements of each site.

Some of the more sophisticated on-line distributed processing systems are capable of continuing processing data at the local level for some time even when the communications link is down, or if the host computer is not operating. On-line updating is then done when all facilities are once again functional.

In other distributed processing applications, a remote intelligent terminal acts as a stand-alone processor during daytime business hours. The terminal is polled by the central computer at night to collect data and update the data base before the next workday. All this can be done without anyone actually being present at the terminal after business hours. In this way, a data base can be distributed and updated daily.

Until recently most intelligent terminals could not perform simultaneous operation of printers, cassettes, card readers, etc., or permit their being shared by two different terminals. In other words if the terminal was busy printing it was unavailable for input.

Three developments have practically eliminated these restrictions:

1. High speed microprocessors with a cycle time of one microsecond or better,

2. changes in architecture design which allow direct contact between the terminal's internal memory and the peripherals at memory speed,

3. parallel connection of peripherals on the same line with the terminal by high-speed data buses. These buses have allowed up to eight devices to be connected to the intelligent terminal at distances up to 7000 feet. Data transfer occurs at speeds up to 20,000 bytes per second.

More advanced terminals of the future will likely require less interaction with the main computer. Additionally, features will be installed which will reduce operator interaction and lower the possibility of errors.

C. TECHNOLOGICAL IMPACT ON SYSTEM DEFINITION

Most of the areas surveyed hold great promise in satisfying the specific requirements of the system definition. Therefore, little change will be presented here. The minicomputer industry has recognized the potential profits of business applications and is well along in production of machines which can adapt to data base management as well as interface with other components such as COM devices. The production of more advanced "intelligent" terminals can provide flexibility for operator interaction with the main computer as well as relieve the main computer of many of the more tedious chores. Other I/O devices are also becoming more sophisticated and require less main processor time for control.

The only technology area which appears to be somewhat questionable is that of mass storage systems. Developments in this area appear to hold great promise but at present, technical interface difficulties might preclude immediate use. Also, access time would appear to be too long to operate in ar on-line system. This is not to eliminate the possibility of their use but to emphasize that particular attention must be paid to this industry when future iterations are made and the impact on the system definition is assessed.

Perhaps the most critical issue derived from the survey is that of interfacing the various devices into a system. All facets of the computer industry appear to be making great strides with new innovations emerging almost weekly. But, with this accelerated progress, increasingly more emphasis must be placed upon efficient system design to alleviate the possibility of degration due to dysfunctional interfacing techniques.

D. OPERATIONAL SYSTEMS

The requirement for configuration and data management similiar to the needs of NSWSES exists in other organizations within the Navy and in industry. In order to develope an appreciation for the approach other organizations have taken to configuration and data management and to observe the application of current technology, operational systems within the Navy and related industry were reviewed. The configuration control required by industry in order to insure the original "as designed" technical data is changed to reflect the "as built" component upon delivery to the Navy is very similiar to the configuration control required by NSWSES to maintain the technical data current with changes to fleet systems. This same commonality was observed in other Navy organizations responsible for configuration control. Although there are some variations in each configuration and data management system the problem of configuration control is universal enough that standard software systems have been developed which could fill NSWSES configuration control requirements.

The configuration and data management systems observed at the Pacific Missile Test Center (PMTC), Point Mugu, California and at Lockheed Missile and Space Company, Inc., Sunnyvale, California are described below.

1. A Navy System

The Pacific Missile Test Center at Point Mugu performs the configuration control function for systems under the cognizance of Naval Air Systems Command which is a mirror image of the configuration control performed by NSWSES for systems under Naval Sea Systems Command. This commonality of functions makes possible a direct comparison of the configuration management requirements of the two stations. This is particularly pertinent since PMTC has an on-line system for configuration management in operation which is very similiar to the system envisioned at NSWSES.

The Configuration and Data Management Support System (CADMSS) at Point Mugu serves both PMTC and the Naval Weapons center (NWC) at China Lake, California. It provides on-line query and a data collection system supporting in-service engineering, logistics, configuration and data management. The system is accessed via IBM 3270 compatable data collection stations capable of storing and retrieving management data information. The data stations are linked to the CADMSS data base via telephone network.

The processor is an IBM 370/165 and supporting telecommunications. This system receives, processes and stores data from the CADMSS data stations, as well as retrieving quiried information and generating selected reports for a particular data station.

The CADMSS is comprised of four interacting modules utilizing common data bases. The modules are the Technical Data Module (TDM), the Contract Monitoring Module (CMM), the Baseline Accounting Module (BAM), and the Change Accounting Module (CAM).

The Technical Data Module provides for the identification and control of technical data and for the accounting of changes to the data. Standard on-line query, data entry, and file maintenance techniques service the TDM. Data edit and validation are included in file maintenance routines. On-line query capabilities relate the current revision status of all technical data on file and the status of in-process changes to the technical data on file.

The Contract Monitoring Module (CMM) tracks contract data requirements and hardware deliverables. Data edit and validation are included in all file maintenance routines. On-line query and hard copy report capabilities relate the status of Contract Data Requirement deliverables, hardware delivery status of configuration end items by serial number and contract baseline. The contract baseline information is retained in the parts bill-of-material format for each contract, thus providing a baseline accounting for a specific contract.

The Baseline Accounting Module (BAM) provides a bill-of-material process from which product baselines of equipment are extracted. Data edit and validation are included in all file maintenance routines. On-line query and hard-copy report capabilities relate the baseline definition, component usage, contract baseline definition and contract component usage.

The Change Accounting Module (CAM) tracks the status of all Engineering Change Proposals, deviations, and waivers. The approval cycle status of a change is monitored by date and activity. The impact of a change on other portions of the CADMSS system is provided by the linkages of technical data affected, parts affected, including contract baseline and contracts affected.

The CADMSS was developed as a structured system utilizing a standard data base to provide accurate and timely information. The system was designed with the flexibility to grow to meet future requirements with minimal impact to the basic system. The system provides data validation, ease of maintenance, rapid data retrieval, flexibility in operation and integration.

The CADMSS was designed to minimize training requirements for effective utilization of the system. Specialized training or experience is not required for normal system use. A menu-technique of accessing system functions is utilized to minimize requirements for familiarization with specific program names. Operators follow normal sign-on procedures including password security. After sign-on, the CADMSS executive system directs the program selection based on descriptive names rather than coded program identifiers or numbers.

The automated functions of the Technical Data Module and Contract Monitoring Module described above for CADMSS correspond very closely to many of the responsibilities of the Data Management Division at NSWSES . These functions at NSWSES are currently carried out manually but as demonstrated by the CADMSS system, many of these functions could be automated for a much more effecient and effective operation.

The Baseline Accounting Module and the Change Accounting Module described above for CADMSS correspond to the CIIF and Class 1 Change File respectively as described in Chapter II. The on-line feature provided by CADMSS provides a vast improvement over the batch operation used at NSWSES.

The Point Mugu CADMSS system appears to provide an excellent example of an operational on-line system which could be utilized by NSWSES in the development of the specifications for their own system.

2. An Industry System

The Configuration Accounting System employed at Lockheed Missile and Space Company is primarily concerned with insuring that the "as built" systems are reflected correctly by supporting technical data upon delivery to the Navy. The configuration control required at NSWSES is primarily concerned with maintaining control after systems are delivered to the fleet. However, review of Lockheed's Configuration Accounting System revealed that configuration control systems are very similiar regardless of the specific application. Desired features of particular configuration systems available in industry could be incorporated in the specification of a new system at NSWSES.

Review of the Lockheed installation did provide an opportunity to observe the operational application of the digitilized storage of engineering drawings and an automated drafting system based on this digitilized data.

The Computer-Graphics Augmented Design and Manufacturing (CADAM) system at Lockheed is independent of the Configuration Accounting System. The CADAM system is designed to operate on an IBM 360 or 370 computer but, as discussed under technological developments, automated drafting systems are adaptable to minicomputer applications. The CADAM system can provide a 500 millisecond response time. The system can support up to 14 interactive terminals with 130,000 byte region of core memory without a noticable reduction in response time. A reduced number of terminals would reduce the core memory requirements.

The CADAM system automatically controls release of drawings and prevents unauthorized changes. A key code is input into the program which is accessible only to authorized individuals. The master digitilized drawing file is kept current with a minimum of man-hours effort.

With CADAM, typical tasks at Lockheed resulted in positive timespan savings (23% to 78%) and man-hour savings (25% to 80%). Measured cost savings as high as 63% have been achieved. The above savings include the manufacturing aspect of Lockheed's operation through the use of numerical control systems. This segment of CADAM would not be applicable to NSWSES requirements. However, the ease with which a digitilized drawing can be updated and the automation of the drafting functions still show promise for substantial cost and time savings. In addition, looking to the future when the military specifications may allow the acceptance of engineering drawings in digitilized form makes the consideration of a system such as CADAMS attractive from both a cost and space savings aspect.

E. OPERATIONAL SYSTEMS IMPACT ON SYSTEM DEFINITION

The review of operational systems provided a valuable input to the system definition in that many of the functions which must be performed by the system under development at NSWSES are currently being performed by other operational systems. This is particularly true concerning the Configuration and Data Management Support System (CADMSS) at Point Mugu. The CADMSS system is fully specified and operational. The configuration management responsibilities imposed on Point Mugu are almost identical to the responsibilities imposed on NSWSES. Many of the problems associated with the development of a new system have already been solved by Point Mugu and many more problems will be discovered and resolved before the NSWSES system goes on-line. It is therefore imperative that NSWSES make future iterations, as the system definition at NSWSES is firmed up, in order to take advantage of the knowledge gained at Point Mugu.

One important difference between the Point Mugu system and the system envisioned at NSWSES does exist. The CADMSS system was designed to operate as a tenant on an IBM 360 computer and the system at NSWSES will most likely utilize minicomputers as the central processing units. This difference can be explained however by the great strides which the minicomputer industry has made in satisfying the needs of a data management system since the CADMSS system at Point Mugu was specified. While the minicomputer may not have sufficed when the CADMSS system was specified it now appears that it is fully capable of processing such a data management requirement.

Another area where the review of operational systems has an impact is the digitilized storage of engineering drawings and the automated drafting systems. Only one such system at Lockheed was reviewed but several companies now have this capability and NSWSES should take full advantage of the available knowledge from these systems.

The initial application of new technology and system procedures must be made by some organizations. In so doing, these organizations and the companies solve many of the problems which are inherent in new installations. NSWSES should take full advantage of this process as they develope and finalize their system definition by continuing to review the operational systems available to them and making necessary changes to the system definition.

V. ACQUISITION PLANNING

A. RECOMMENDED ACQUISITION PLAN

The acquisition of an automatic computer based configuration and data management system at NSWSES should be accomplished in a time phased sequence. Completion of each phase of the sequence will result in the defined capability being obtained. It should be noted however, that the phases are not independent. Some decisions, such as the physical facility to house the total system, must take into account the requirements of all phases. Also, decisions made in each phase will limit to some extent decisions which can be made in later phases. Another key factor which ties the phases together is the timing of various segments in each phase. Fig 9 gives the overview of the recommended acquisition process and the following paragraphs provide more details of the process.

1. Phases of Acquisition

PHASE 1 - Integrate the Configuration Item Identification File, the Site File, the Class 1 Change File and the Master Index File into a common data base. Develope a Technical Data Tracking File for technical data requirements similiar to the Class 1 Change File for Engineering Change Proposals. Acquire the central processing units, the interactive terminals and the software operating systems necessary to develope an on-line configuration management system operating on an integrated data base.

PHASE 2 - Develope the capability to digitally store engineering drawings and the capability for computer output to microfilm. This phase will greatly increase the storage requirements over phase 1 and will require either a mass storage system or a library system. In addition, input digital scanners will be required.

PHASE 3 - This phase is a natural follow on to phase 2 and involves the development of the digitalized display of engineering drawings and an automated drafting system. Phase 3 would primarily provide services to NSWSES departments outside the Technical Data Department and would involve both hardware and software for the automated drafting system and display terminals.

The recommended phases of procurement were selected to provide the maximum benefit from the new data management system as early as possible in the system development and to delay the acquisition decisions which are less clearly defined at the present until a later point in the sequence. Phase 1 in the acquisition process does not require any technological accomplishments that do not already exist today. In addition, software systems are in existence which can easily be adapted to the phase 1 requirements. Completion of phase 1 would provide a major improvement in the configuration and data management system of the Technical Data Department. Completion of phase 1 will give the department complete in-house capability with regard to their configuration and data management system and will make the progression to phase 2 much eaiser and reduce disruption of services.

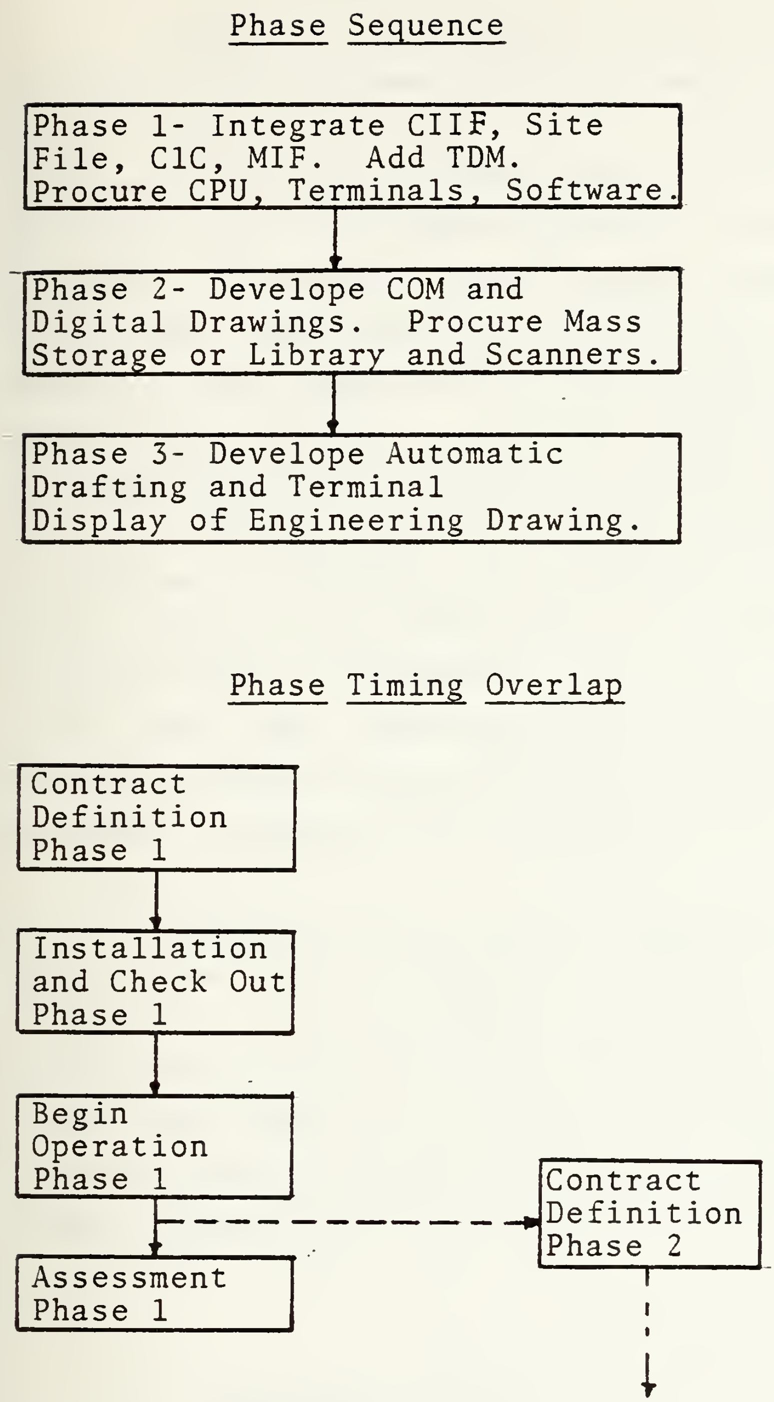

Figure 9 - PHASE TIMING

Phase 2 will provide the Technical Data Department the capability to meet the long term future demands which will increase as the volume of data and number of users increases. However, before phase 2 can be implemented some problems must be resolved and some technological questions answered. Currently the military specifications do not allow the acceptance of engineering drawings in digital format. Some digitalized drawing systems do not provide the specified resolution. To determine the full potential of a digitalized engineering drawing system it must be determined to what extent the contractors and other organizations which interface with NSWSES will convert to similiar systems which would allow the interchange of engineering drawings in digital form. In addition, it is not certain at the present time that the technology of the mass storage systems or a library system would provide the response time that would be required to maintain the engineering drawing file.

Phase 3 would provide the logical benefit available once phase 2 is complete. Phase 3 does not pose any particular technological problems but implementation of phase 3 will call for close coordination within NSWSES since other departments will effectively become tennants of the Technical Data Department's system and questions of response time, priority systems, etc. become important.

2. Acquisition Timing

The establishment of a timing sequence similiar to that shown in Fig 9 serves three major functions. First, this will allow for an orderly sequence of procurement which can be merged with the budget cycle. Second, the attainment of various operational objectives can be anticipated. Third, and perhaps most important, the assessment of one phase can be used to influence decisions in the contract definition of the subsequent phase thereby providing a total system which most nearly meets the overall operational objectives.

B. RECOMMENDED ORGANIZATION PLAN

The acquisition of an automated computer based configuration and data management system within the Technical Data Department at NSWSES will greatly enhance the department's ability to perform it's mission. At the same time, the development will represent a major capital expenditure for NSWSES and will impact the billet requirements particularly within the Technical Data Department. In order for NSWSES to 1) realize the full benefit from implementation of the new system, 2) make a smooth transition from the current system to an in-house computer based system without disruption of current services and, 3) minimize the adverse impact on personnel, it will be necessary for the upper levels of management at NSWSES to be fully aware of and in support of the objectives of the new system. It is therefore recommended that a steering committee be established which shall be responsible for the overall coordination of the acquisition to insure that it is integrated with all of the NSWSES operations and with other activities external to NSWSES.

In addition, it is recommended that subcommittees be appointed to provide detailed guidance for specific segments of the system acquisition. A recommended committee arrangement is shown in Fig 10. The following paragraphs provide general guidance areas for which it is felt each committee should be responsible. A recommendation for committee membership is made only for the steering committee where it is felt by the authors that representation of specific units within the NSWSES organization is necessary to ensure overall coordination of the system development effort. The subcommittee membership should be made up of personnel from NSWSES who have particular technical or other expertise in a given area and an appreciation for the operational objectives of the data management system. Active membership on any of the committees will likely vary at different stages of the acquisition.

1. The Steering Committee

It is recommended that the Department Head of the Technical Data Department be appointed as the steering committee chairman. His position as a Department Head places him in a unique position of having a working knowledge of the operational objectives of the system and a senior management position which allows ready access to other senior management positions to insure that the data management system becomes an integral part of the entire NSWSES organization. Within the Technical Data Department it is recommended that each Division Head be appointed to the committee tc insure that the unique requirements of each division are identified and an integrated data base is developed which will satisfy these requirements while maintaining the interrelating links which make an integrated data base functional.

The long range planning group at NSWSES should be represented on the committee to insure that NSWSES command requirements are considered throughout and to insure that the acquisition is integrated with the overall NSWSES operation.

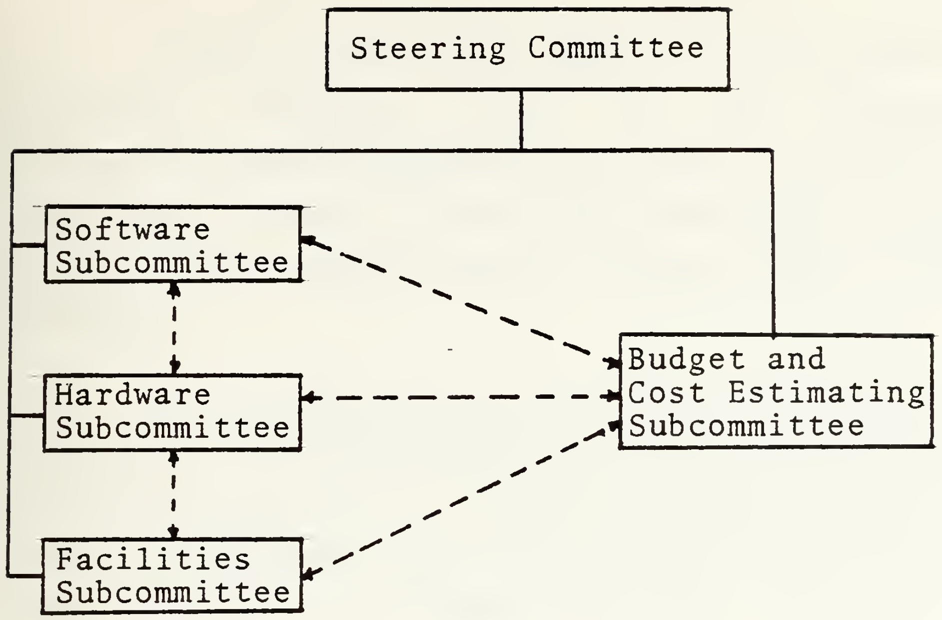

Figure 10 - RECOMMENDED ORGANIZATIONAL STRUCTURE

During phase 2 and phase 3 of the system acquisition additional members, such as the engineers and the engineering drafting personnel should be included as active committee members. This will insure that the full benefit of the data management system within their departments is realized.

The steering committee should determine the overall objectives for the acquisition. It is recommended that the variables discussed in Chapter III be used as the basis for these objectives and projection of system requirements. These variables are repeated here for clarity.

1. Navy Shipbuilding Program - physical size of the Fleet

2. System Deployment - number of systems maintained, number of end users

3. New Responsibility Areas - change in user needs, change in NSWSES cognizant systems, change in responsibility for system currently managed only in part

4. NSWSES Personnel Manning Levels - need for increased productivity

The steering committee should set forth a policy statement giving such general guidelines as schedule for implementation, integrated data base concept, on-line operational requirements, known cost and time constraints, etc. This policy statement will provide the various subcommittees a framework in which to work.

The steering committee should be responsible for evaluating the possibility of revolutionary changes which may occur in the Technical Data Department's responsibility for configuration management, such as, the possible inclusion of the underway replenishment data base. If revolutionary changes are likely to occur the impact must be reflected in the data management system acquisition to insure that the system is fully capable of meeting the new demands.

The steering committee should consider the various alternatives which are developed by the subcommittees and be responsible for making major alternative tradeoff decisions to insure that the overall objectives of the system are met.

2. <u>The Hardware Subcommittee</u>

The hardware subcommittee should be responsible for the selection of system hardware which will most effectively and economically support the system objectives. This will require close coordination with the software subcommittee to ensure that the operating system chosen is fully compatable with the hardware selected. The hardware subcommittee should make iterations through the technological review cycle and operational system survey as discussed in Chapter IV.

Some of the basic considerations which the hardware subcommittee should study are given below. These areas are not intended to be all inclusive but only a suggestion as to the type of considerations for which the hardware subcommittee should be responsible.

AVAILIBILITY - Hardware should be chosen which is close to the state of the art in order to prolong the life of the overall system. This must be balanced againist the requirements that the hardware be available when required and fully capable of operation in the anticipated manner.

MAINTAINABILITY AND REPAIRABILITY - A decision must be made as to whether NSWSES will develope it's own maintenance and repair capability or rely on the contractor for maintenance and repair. This will involve consideration of both cost and possible system down time.

OPERATOR TRAINING - The time, disruption, and cost of training personnel must be considered and it is desirable that training time be kept to a minimum.

MODUALARITY - The hardware chosen must not only fulfill current system requirements, but must also be capable of expansion to meet future needs. This is particularily important as the hardware selections made for one phase must also support the additions of later phases.

3. The Software Subcommittee

The software subcommittee must work in close conjunction with the hardware subcommittee to develope an operating system which fully exploits the capability of the hardware and fulfills the requirements of the overall system. Some of the considerations for which the software subcommittee should be responsible are given below. These are suggested areas and the list is not all inclusive.

DOCUMENTATION - The documentation requirements from the design phase throughout the system life cycle cannot be over emphasized since it forms the basis for system understanding and operation. This documentation should include computer programs, manuals and procedures, equipment and facility lay-out, computer operating procedures, training materials and training programs.

USER TRAINING - In addition to the training documentation identified above the subcommittee should develope a training program for the users of the system.

STANDARDS - The development of standards which must be followed by all users of the system is very important if an integrated data base is to be effective.

INFORMATION FLOW - A study of information flow requirements should be made to insure that all required information is made available in a timely fashion and that redundent or useless information is not processed.

ACCOUNTABILITY - Procedures should be developed which insure that only authorized personnel interact with the system and that these personnel be accountable for actions taken.

BACK-UP PROCEDURES - Consideration must be given to methods of operation which can be utilized if the system is inoperative. This would include assurance that essential data is maintained and that emergency procedures exist which would allow use of this data if required.

4. The Facilities Subcommittee

This subcommittee should determine the facility requirements for support of the system. The committee must take an overall view of all three phases to insure that allowance is made for the increased facility requirements as the phases are installed. The possibility of utilizing existing buildings, upgraded to support the system, should be investigated. Close coordination with the hardware committee will be required to insure that the facilities developed are compatable with the space and support requirements of the hardware.

5. The Budget/Cost Estimating Subcommittee

This subcommittee must work in close conjunction with all the other subcommittees to insure that all the requiremnts are considered and that accurate cost estimates are developed to support preparation of the budget submissions. The subcommittee should be responsible for insuring that the time and cost constraints prescribed by the steering committee are observed and that necessary tradeoffs between the requirements identified by other subcommittees are presented to the steering committee for final decision.

VI. RECOMMENDATIONS FOR FUTHER STUDY

In writing this thesis, the authors have concentrated on a managerial approach to properly organize future investigation and coordination efforts. After the need is completely justified, NSWSES should turn to the more detailed studies which will help to more rigorously formalize the parameters of the proposed system. These studies may be made by NSWSES personnel, contractors, or Naval Postgraduate School students depending upon cost and time constraints.

Another alternative, which is favored by the authors, is to assign each of the study areas as a specific responsibility of one of the committees discussed in Chapter V. These committees should be responsible for collecting data, analyzing the data in light of specific user requirements, and making detailed recommendations to the steering committee. This should be a natural product of the acquisition process and need not delay the beginning of the system development cycle.

The belcw recommended studies are not all inclusive. Additional investigations will be required as the acquisition process continues.

1. Analysis of the expected file sizes projected into the relevant time frame. This should include an analysis of the mass storage requirements for the various functional areas of the system definition.

2. Analysis of the access times required for each classification of work. For example, routine file

maintenance times would probably differ from the times required for the extraction of engineering drawings.

3. Simulation and analysis of the proposed system using GPSS or other simulation languages to provide a model for other studies. This work might well be accomplished by Computer Science students at the Postgraduate School in conjunction with the hardware subcommittee.

4. A tradeoff analysis of a complete on-line system verses on-line query and update/transaction file with a batch file maintenance concept.

5. Analysis of the actual dollar savings associated with digitalized drawings.

6. Analysis of the actual dollar savings associated with increased productivity of personnel. This analysis can be conducted in phases as the various functional areas are included as users of the system.

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